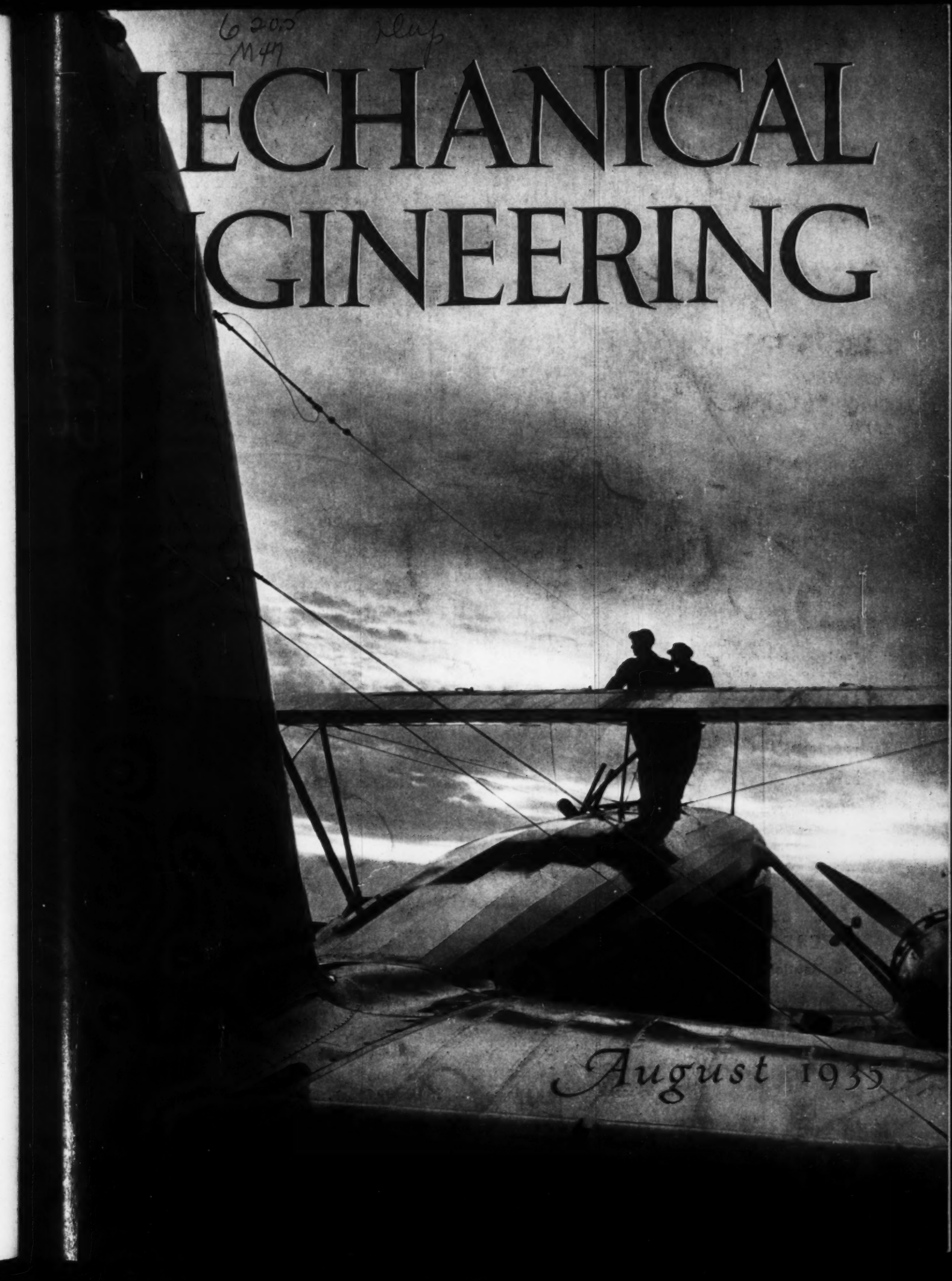
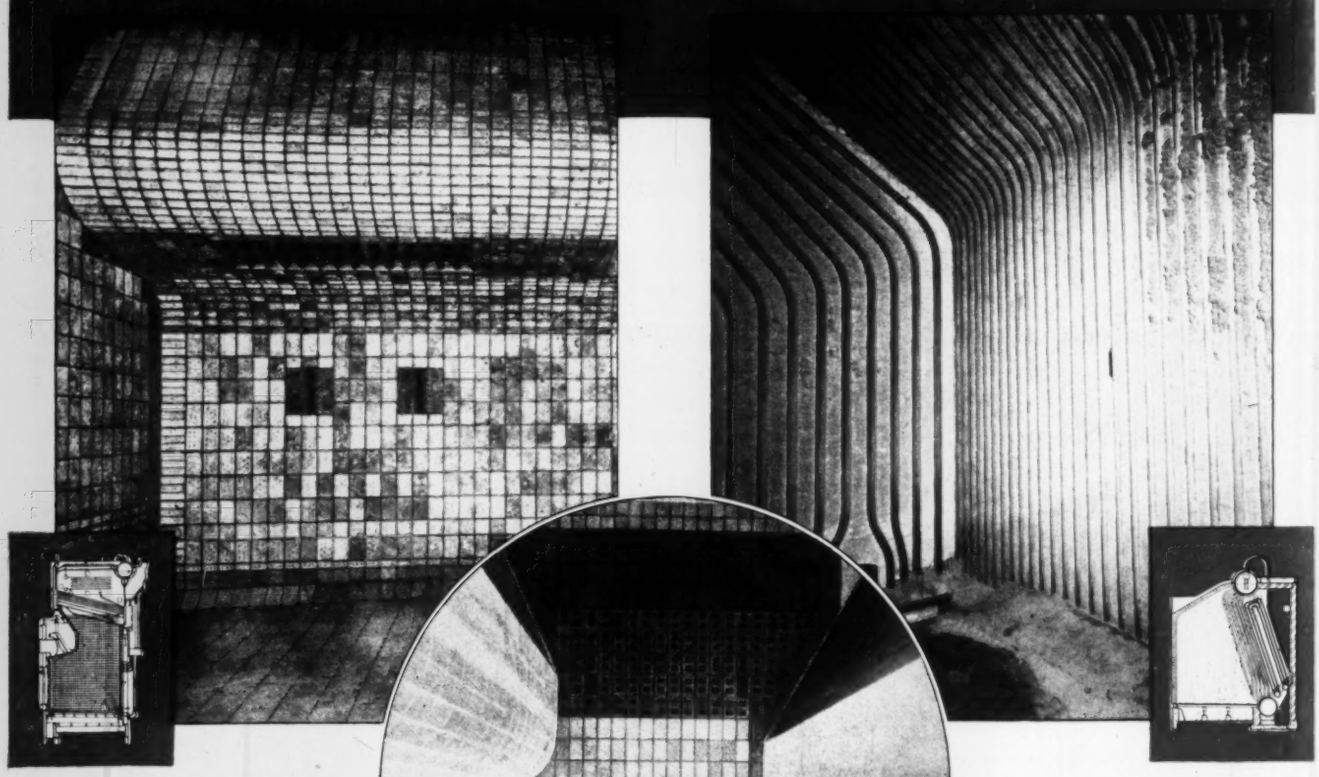
620.5
M47

MECHANICAL ENGINEERING

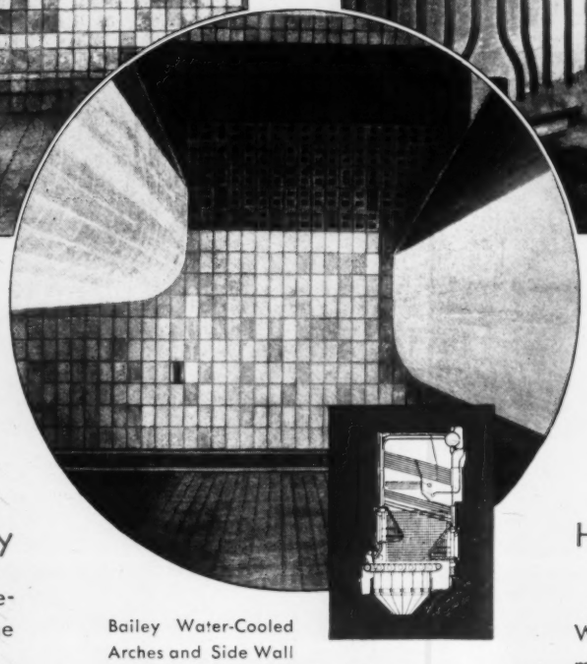


August 1935

BAILEY WATER WALLS



Interior of Bailey Water-Cooled Slag-Tap Furnace showing block-covered side-wall and floor and multiple-inter-tube pulverized-coal burners located in the arch.



Bailey Water-Cooled Arches and Side Wall of a chain-grate stoker-fired furnace under a B&W Boiler.

Bailey Water-Cooled Furnace Construction of the Integral-Furnace Boiler showing bare-tube rear wall, stud-tube side wall, and block-covered water-cooled floor.

HIGH AVAILABILITY

Operating records show furnace-availability as high as that of the best boilers.

FOR BEST OVERALL PERFORMANCE

Coordination with other B&W Equipment makes possible a complete boiler unit capable of producing steam at lowest cost when all factors are considered.

WIDELY APPLICABLE

Used to advantage with any fuel or firing method, for small as well as large boilers, for partial or complete water-cooling.

HIGH COMBUSTION EFFICIENCY

Wide variety of wall surfaces permit furnace temperature high enough to prevent excessive carbon loss at all ratings.

WORLD-WIDE USE

More than 750 installations throughout the world. In this country alone, under boilers having total output of over 92,000,000 pounds of steam per hour.

The Babcock & Wilcox Company . . . 85 Liberty Street . . . New York

BABCOCK & WILCOX

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 8

Contents for August, 1935

THE VELOX STEAM GENERATOR . . . . . *Adolphe Meyer* 469
"THE COMET"—HIGH-SPEED TRAIN . . . . . *Karl Arnstein* 479
A NEW CURRICULUM IN MECHANICAL ENGINEERING . . . . . *F. L. Eidmann, W. A. Shoudy, T. Baumeister, Jr.* 483
MECHANICAL PROPERTIES OF MATTER . . . . . *Irving Langmuir* 486
METAL CUTTING . . . . . *Hans Ernst, M. Martellotti* 487
45,000-HP TURBINE FOR WHEELER DAM . *F. H. Rogers, R. E. B. Sharp* 499
AMERICA'S OUTPUT AND INCOME . . . . . *Donald S. Tucker* 507
THE CINCINNATI MEETING 509
NOMINATIONS FOR OFFICERS OF A.S.M.E., 1935–1936 527

EDITORIAL 467
ENGINEERING PROGRESS 513
REVIEWS OF BOOKS 522
A.S.M.E. BOILER CODE 526
WHAT'S GOING ON 527

DISPLAY ADVERTISMENTS 1
WHAT'S NEW 12
PROFESSIONAL SERVICE 29
CLASSIFIED ADVERTISEMENTS 30
INDEX TO ADVERTISERS 32

OFFICERS OF THE SOCIETY:

RALPH E. FLANDERS, *President*

ERIK OBERG, *Treasurer* C. E. DAVIES, *Secretary*

PUBLICATION STAFF:

GEORGE A. STETSON, *Editor* FREDERICK LASK, *Advertising Mgr.*

COMMITTEE ON PUBLICATIONS:

S. W. DUDLEY, *Chairman*

S. F. VOORHEES W. F. RYAN

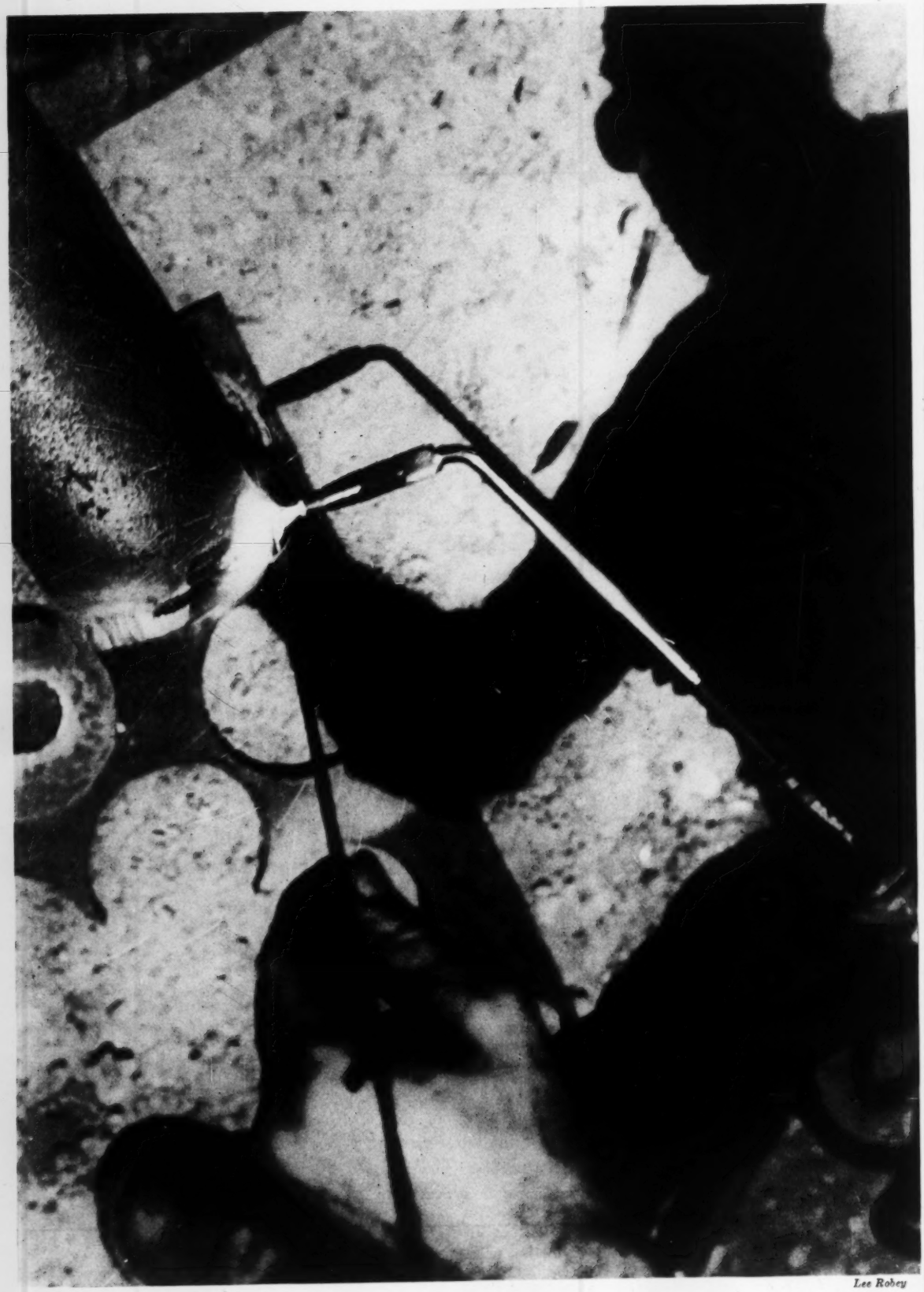
G. F. BATEMAN M. H. ROBERTS

ADVISORY MEMBERS OF THE COMMITTEE ON PUBLICATIONS:

E. L. OHLE, ST. LOUIS, MO. E. B. NORRIS, BLACKSBURG, VA. A. J. DICKIE, SAN FRANCISCO, CAL.

Junior Member, O. B. SCHIER, 2D

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted 1935, by The American Society of Mechanical Engineers.



Lee Robey

"Fire That Is the Soul of Every Art"

VOLUME 57
No. 8

MECHANICAL ENGINEERING

AUGUST
1935

GEORGE A. STETSON, *Editor*

The Rice Lecture

THE splendid choice of the Committee on Meetings and Program of The American Society of Mechanical Engineers in inviting Dr. Adolphe Meyer to deliver the Calvin W. Rice Memorial Lecture at Cincinnati deserves especial commendation. Dr. Rice thought in international terms. In his philosophy, engineering was devoid of nationalism. His own friendliness and hospitality to engineers from over seas opened many an opportunity in this country that might otherwise have remained closed to them; and, because hospitality begets hospitality and friendliness kindles similar sentiments in others, American engineers profited in their trips abroad because they bore Dr. Rice's endorsements. That this spirit still lives in such an interchange of courtesies as led the Committee on Meetings and Program to invite a distinguished Swiss engineer to deliver in this country a technical lecture named for Dr. Rice insures the enrichment not only of that feeling of international friendliness so earnestly fostered by him, but also of the literature of mechanical engineering as well.

Apply Modern Physics

DR. IRVING LANGMUIR, A.S.M.E. Holley Medalist for 1934, in his address at Cincinnati that appears elsewhere in this issue, threw out a suggestion that engineers will do well to consider. Dr. Langmuir pointed to the fact that physicists today tend to crowd into the extreme outposts of their advancing science, with the result that there is today an ungrasped opportunity for trained men who will devote their lives to the study of the properties of matter in terms of atomic theory.

Few engineers will feel themselves qualified to develop the opportunities that exist for studying thoroughly the mechanical properties of matter, but from the results of the applications of modern physics and chemistry there may follow, to quote Dr. Langmuir, "materials having new mechanical properties." These materials and a knowledge of their properties, as well as more thorough understanding of those of existing materials that would assist in their treatment and in cutting and forming them, would be of utmost importance to engineers. A sympathetic attitude toward the work which Dr. Langmuir says should be done will be of great help and encouragment to those who are competent and willing to carry it on.

Income and Capacity to Produce

IT IS a constant temptation to comment every month on the reviews of books on economic subjects of interest to engineers that the Department of Economics at the Massachusetts Institute of Technology, under the sponsorship of the Management Division of The American Society of Mechanical Engineers, is contributing. That the books reviewed would reach the attention of many readers through other sources is, of course, incontestable. But it must be admitted that the economics faculty of a great engineering school holds more closely the point of view of engineers in their approach to economic studies and is more closely alive to the subjects that affect engineers than most specialists would be.

It will readily be admitted that engineers are employed and suffer unemployment with the rise and fall of the economic health of the capital-goods industries in particular, and that their especial talents are required by those who invest money in productive capacity and for the development of new industries. Hence they cannot be unaffected by changes in the national attitude toward investment and credit policies. Much discussion in the early stages of the depression to the effect that our difficulties were results of overcapacity to produce, overinvestment, and ill-advised investment in industries assumed to be overcapacitated not only oversimplified the problem but found acceptance even among some engineers. Such ideas pervaded, as the A.S.M.E. Committee on the Capital Goods Industries pointed out in its reports published in MECHANICAL ENGINEERING, the philosophy upon which many NRA codes, of recent memory, were based, and have threatened to become a guiding principle of the Administration's efforts to socialize industry.

Certainly the facts and the truth of this vexatious and complicated problem need thorough study and sympathetic interpretation. The zeal of planners to limit investments to projects and in amounts that seem prudent and desirable to a small group needs to be curbed with common sense; and a realization that the philosophical principle of uncertainty operates in social, economic, and political matters to the confusion of foresight, no matter how informed it may consider itself to be, should penetrate the consciousness of all who attempt the Jovian rôle at the expense of their fellow men. There is still much to be said for the principle that the net result of innumerable individually determined courses of action,

even if entered into in the spirit of self-interest, may turn out better for the human race than attempts on the part of a few to guide the destinies of all. Planning must start with the individual at the bottom. Planning that starts at the top imposes a despotic, even if it be well-intentioned, coercion on individuals.

Developments in Engineering Education

THE education of engineers is a matter of concern for all members of the profession. Training for the successful practice of mechanical engineering is a too-easily stated objective. The method, the curriculum, and the length of time to be devoted in formal education are not easy to determine, nor are educators and practitioners ever agreed upon them. The breadth of the field of mechanical engineering, its constantly changing techniques and duties, the variety of functions that engineers perform, and the usual evolution of the individual into positions that are more and more administrative and correspondingly less technical, add complications. Hence, any contributions to the solution of the problem should receive thoughtful consideration; and the brief résumé of the Columbia plan, presented in this issue by three members of the curriculum committee of the mechanical engineering department of that institution, deserves study on this score.

Institutions attempt to solve their problems according to the peculiar conditions they face and the educational philosophies of their faculties. Dean Schneider's well-known cooperative system, described by him in our July issue, which has been adopted in various forms by several institutions, combines practical industrial experience with academic instruction; Columbia, Harvard, and Johns Hopkins emphasize work of so-called graduate caliber; the proximity of great engineering establishments has given peculiar advantage to variants of the cooperative idea at Pittsburgh, M.I.T., and Union; while at Yale Dean Doherty is working out a system designed to turn out a superior, broadly educated, and intellectually aware individual. These are but a few of the plans that come casually to mind.

The investigation by the Society for the Promotion of Engineering Education undertaken a dozen years ago provided institutions with a factual basis for comparing their educational procedures and assisted in reducing the number and variety of specialized courses attempted by some. The flurry caused by the introduction of industrial or administrative engineering courses and the more recent need for instruction in aeronautics have shown how curricula must be extended from time to time to meet the needs of the ever-expanding field of mechanical engineering. Moreover, the recent depression has given an opportunity for those who fear overproduction and look upon engineering as a profession that must become a closed one, like medicine, to urge their point. Against them the voices of others have consistently been heard; most recently that of President Wickenden in a paper in the May issue of *Electrical Engineering*.

So the interest and the discussion grow, and involve not only education alone, but the profession as a whole as well. Most encouraging of the organized attempts in this broader field is that undertaken by the Engineers' Council for Professional Development, whose fourfold program of guidance, accrediting of engineering colleges, professional training in post-college years, and professional recognition covers the entire educational process. With so much moving in fields of engineering education, schemes for improving the curriculum and teaching methods should find a favorable environment in which to be tried.

Textile Work Assignments

IT HAS been our privilege to inspect the reports of the three Textile Work Assignment Boards created last year by order of the President following the Winant report on the textile industry. The boards, of each of which Mr. W. A. Mitchell was chairman and on each of which were representatives of employers and employees, studied in particular the problems presented by the "stretchout," about which our readers have been reliably informed through papers by Elliott Dunlap Smith and R. C. Nyman, in the silk, wool, and cotton industries. In particular they commented on recommendations of the Winant board relating to complaints of workers arising out of changes in work assignments and the establishment of regional labor boards.

It is gratifying to note that the three boards were virtually unanimous in declaring that the great variety of conditions met with in individual plants makes the setting of work assignments a matter for a study of the actual conditions peculiar to every plant, that it is impractical to set up standard assignments, that regional boards should not be appointed, that it is unjust and unwise to require a mill to secure authorization to increase work assignments or observe a waiting period subsequent to filing a petition to change work assignments, that in many mills employees have not suffered from the effects of specialization resulting in the "stretchout" but have benefited where it was wisely administered, that they do not discourage the use of improved machinery, better methods, and scientific management, and that a central work assignment board (one for each of the three industries) would provide a tribunal where employers and employees could submit their problems and grievances for study, investigation, and equitable decisions. While this last recommendation may be over-optimistically expressed in view of some of the notable failures of peacable methods of settlement (compare, for example, the experience of the Pequot Mills related by Nyman in our February issue), the suggestion is at least reasonable. Differences of opinion on the jurisdiction (silk or cotton) under which the rayon plants should come may be less compelling since the dissolution of the NRA Codes and do not seem unsurmountable.

THE VELOX STEAM GENERATOR

Its Possibilities as Applied to Land and Sea

By ADOLPHE MEYER

BROWN, BOVERI & COMPANY, BADEN, SWITZERLAND

THE principal aim in the development of steam generators during the last few years has been to design and manufacture larger units working at higher pressures and temperatures than in the past. Most firms have tried successfully to develop their own designs of this type of high-pressure boiler, but comparatively few of these designs have been departures from the well-known types of low-pressure boilers. While a few of these boilers incorporate new and interesting ideas in the production of steam and the regulation of combustion, nothing has been done to improve materially combustion itself or the rate of heat transmission. It is in relation to these last two points that the Velox boiler differs essentially from most boilers which have been in use up to now. Its name "Velox" refers to the high velocity of the flue gases, used to obtain exceptionally high heat transmission, as well as to the property of producing steam in a few minutes from cold and of adapting itself to widely varying loads in a few seconds.

The development of the Velox boiler is founded on studies and research work carried on some years ago in connection with the supercharging of Diesel engines and with the design of an oil turbine. Heat losses which occurred in cooling gas-turbine nozzles, in which the speed of the gases was far in excess of the velocity of sound, could only be explained by heat-transfer figures far above anything that could be expected by extrapolating the existing formulas of heat transfer to the prevailing conditions. There was then conceived the idea of using this feature, which in the gas turbine produced a heavy loss, to advantage by applying it to a steam generator.

Intensive research work with a small combustion chamber and a single tube in which velocities up to and exceeding the velocity of sound were produced gave very interesting results as shown in Fig. 1. The results showed that if such velocities could be economically obtained and applied to steam generators, the heat-transmitting surfaces could be reduced to about one-tenth of those of existing boilers with a corresponding saving in space and weight. The realization of such gas velocities does, of course, cause pressure drops far in excess of those occurring in ordinary boilers, and combustion under pressure in a tight combustion chamber had to be resorted to.

The question how to produce this pressure so economically as not to impair the efficiency of the new steam generator was first answered by the use of an explosion cycle for combustion and an exhaust-gas-driven turbo-blower, which had only to give about one-quarter of the final pressure obtained by the explosion of the fuel. It was therefore feasible to put the gas turbine at the end of the gas stream which goes from the combustion chamber through the evaporator, superheater, and preheater. Thus the gas arrived at the gas turbine with such a low temperature that it could be cooled down by the expansion in the gas turbine to a temperature below that of the surrounding air. As the power thus gained from the expanding exhaust gases is entirely recovered in the blower as heat put into the air, there is, at least theoretically, a possibility of getting more heat into the boiler than is supplied by the fuel. As this heat ratio greater than one had wrongly been termed an efficiency greater than 100 per cent, a lengthy and rather heated discussion took place in the leading British technical papers some time ago, in which everything was said that can be said about this interesting problem.

Unfortunately the scheme did not work out well because of the purely practical difficulty of getting a uniform mixture of oil and air and a complete combustion in the combustion chamber of the 10-ton experimental boiler, the chamber of which was of enormous size as compared to the space in which combustion takes place in a Diesel or gas engine.

While the development of the explosion-cycle steam generator, which took the best part of three years, was going on

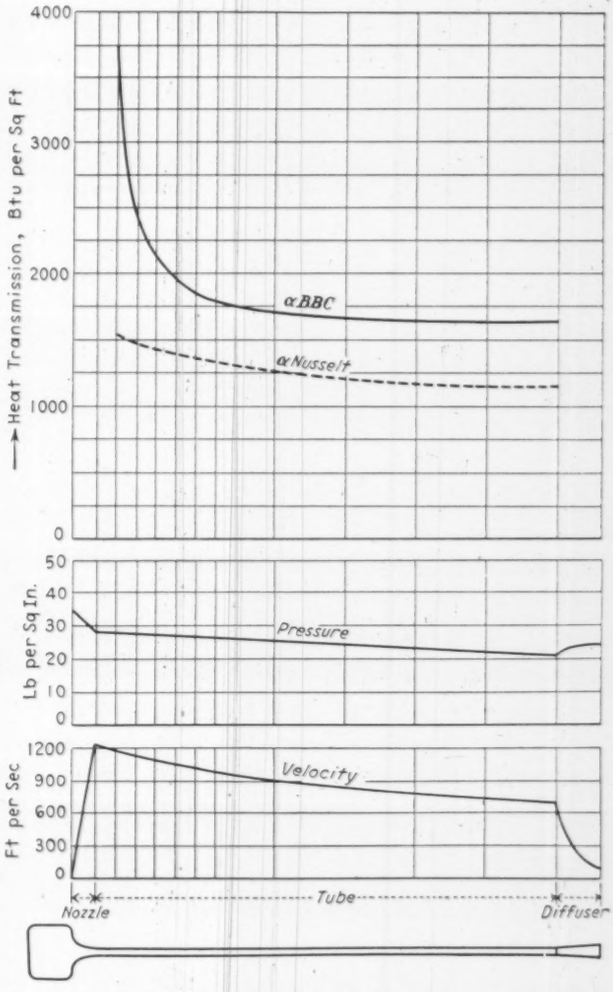


FIG. 1 HEAT TRANSMISSION, PRESSURE DROP, AND VELOCITY OF FLOW IN A TUBE CONNECTED TO A SMALL COMBUSTION CHAMBER

The Second Calvin W. Rice Memorial Lecture, delivered at the Semi-Annual Meeting, Cincinnati, Ohio, June 17-21, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

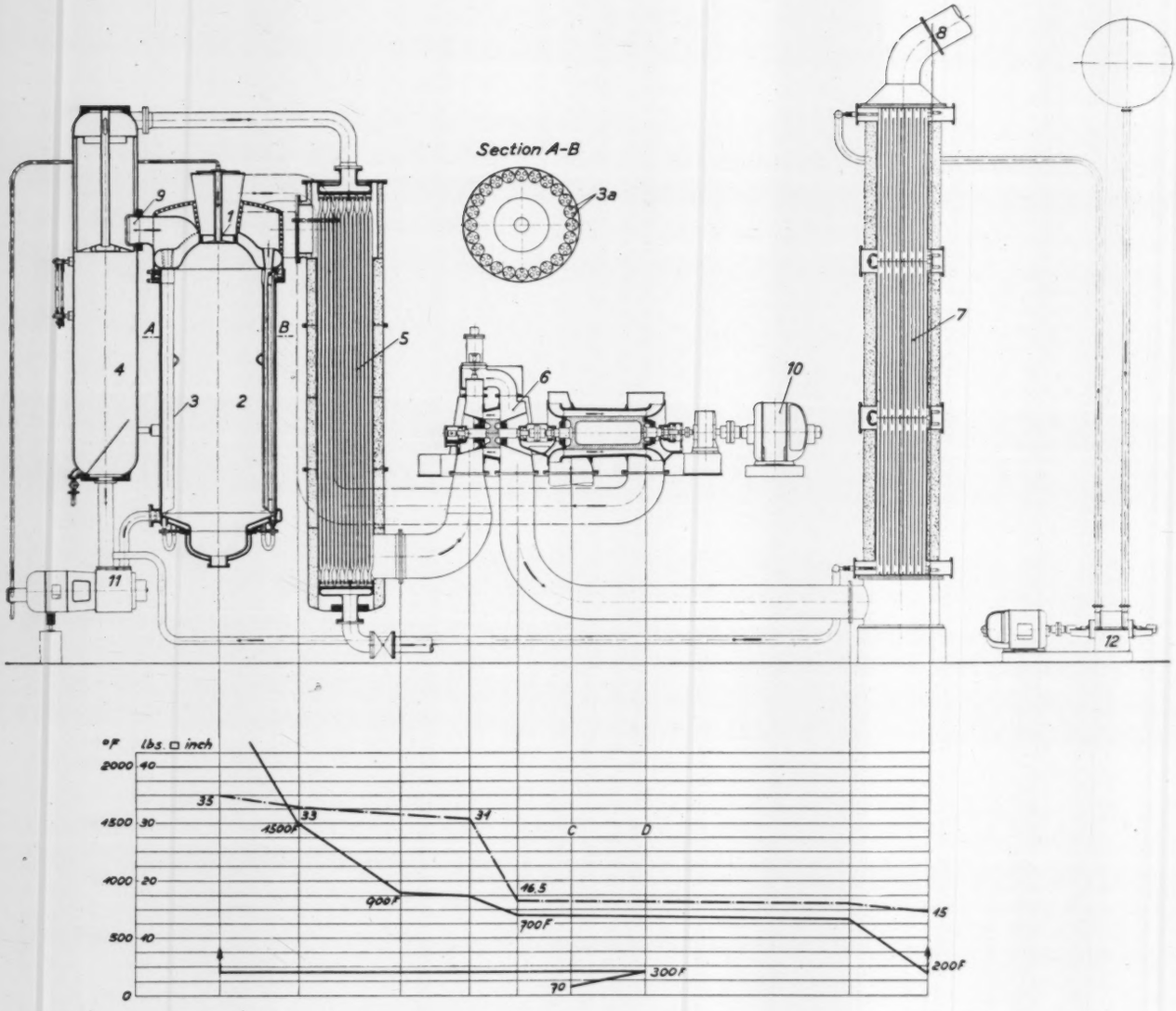


FIG. 2 DIAGRAMMATIC OUTLINE OF VELOX STEAM GENERATOR, SHOWING TEMPERATURES AND PRESSURES IN VARIOUS PARTS OF THE APPARATUS

the efficiency of the exhaust-gas turbine blower, developed for the introduction of the Buechi system for supercharging Diesel engines, had been so improved that it was possible to produce the full combustion pressure with the turbo-blowers and change over from explosion to continuous combustion. To this end, however, it was necessary to displace the gas turbine so that it would receive gases of sufficiently high temperature to enable it to produce the necessary power for driving the blower without the necessity of cooling the turbine. These conditions can be accomplished by placing the gas turbine between superheater and preheater in a zone of temperature around 930 F.

Velox boilers, of which more than 20 units have been built in sizes ranging from 4 to 75 tons of steam per hour, for pressures up to 600 lb per sq in. and temperatures up to 850 F, are all of the continuous-combustion type, and the following description as well as all further data given refer to this type.

I—DESCRIPTION OF VELOX STEAM GENERATOR

Fig. 2 represents a steam generator of the Velox type, and indicates the temperatures and pressures prevailing in its different parts. The combustion of the fuel takes place in the combustion chamber 2 where air and fuel enter through the burner 1; the air at a pressure of about 35 lb per sq in. abs and the fuel at about 300 lb gage. The gases give up part of their heat content by radiation to the external walls of the evaporator tubes 3 which line the wall of the combustion chamber. More heat is transmitted by convection while the gases pass upward through the internal tubes 3*a* of the evaporators to the exhaust flue-gas collecting chamber. Thus the initial temperature of combustion is reduced to about 1500 F, while the pressure drops to about 33 lb abs. With this temperature and under this pressure the gases enter the superheater 5, to leave it cooled to about 900 F at a pressure of about 31 lb. The gas turbine 6, which is then entered, causes the flue-gas temperature to drop to about 700 F while the pressure drops to about 16.5 lb abs. The corresponding heat drop, apart from small radiation and bearing losses, is entirely converted into mechanical energy and transmitted to the blower where it is reconverted into heat with a corresponding rise in the air temperature. Finally, the gases escape through the feedwater

heater 7 which forms part of the chimney. From thence they continue, through the chimney itself, to the atmosphere, where they leave cooled to about 200 F.

The water and steam circuit is as follows:

The make-up water is fed by the feed pump 12 through the preheater 7 to the separator 4, where it mixes with the evaporating water. This water is kept in continuous circulation by the circulating pump 11 which pumps it through the combustion chamber 2 and evaporating tubes 3 back to the separator 4 at the rate of about ten times the full-load evaporation.

The circulating pump gives the circulating water a sufficient pressure head to impart a high velocity to the steam and water mixture which is forced through nozzles into a vertical drum and the steam and water are thus separated by centrifugal action. The separating capacity of this centrifugal separator is about 100 to 200 times greater than that of the normal drum. The water then falls through a small gap in the lower partition of the separator, while the steam enters the superheater 5, where it is superheated to the desired amount for use in a steam turbine.

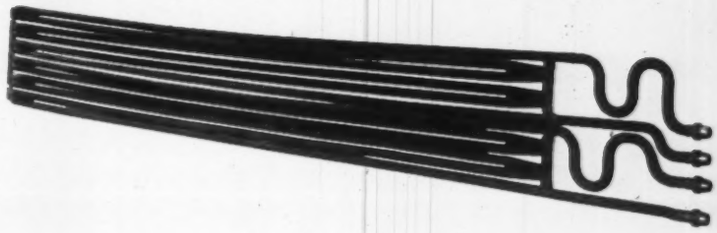


FIG. 4 SUPERHEATER ELEMENT

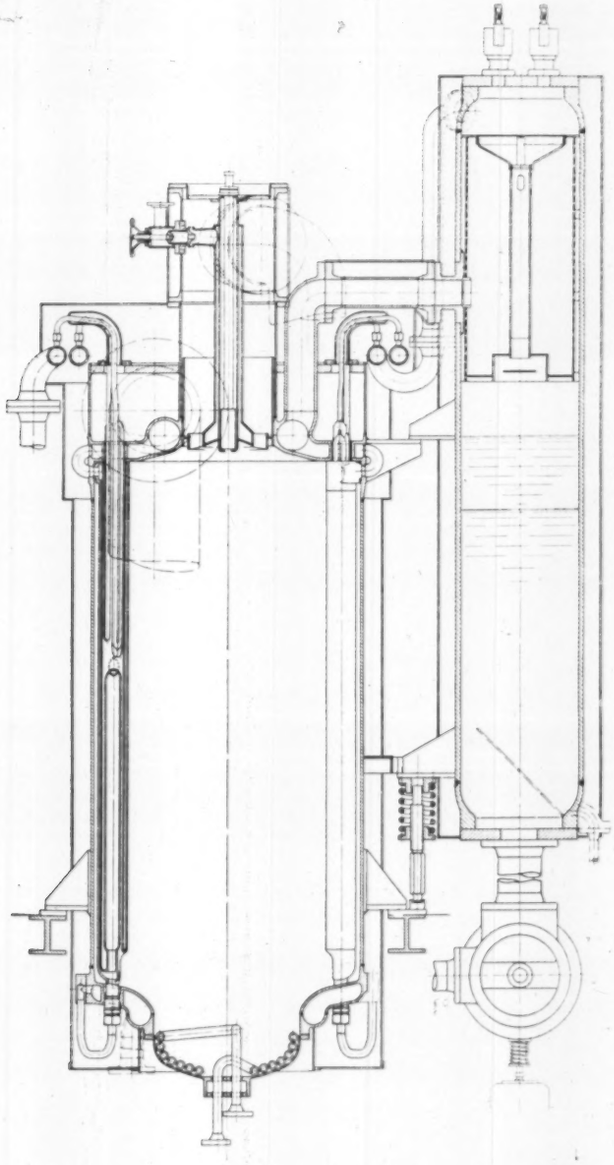


FIG. 3 SECTION THROUGH A VELOX STEAM GENERATOR WITH SUPERHEATER TUBES BUILT INTO EVAPORATOR TUBES AND A BURNER FOR OIL AND GAS FIRING

CONSTRUCTION

Apart from the scheme itself, certain new features will be of interest. The evaporator tubes lining the wall of the combustion chamber to protect it from radiant heat, shown in Fig. 3, are bolted to the wall at the outlet end and are guided so as to expand freely on the inlet end. Thus they can be removed from the chamber with ease. The inner tubes, which have nozzle-shaped inlets, show a remarkable diffusing action. They tend to re-transform kinetic energy into pressure, due to rapid cooling of the passing gases with a corresponding reduction in volume. (See Fig. 1.) The flue gases pass the superheater elements (Fig. 4) in a longitudinal direction, the tube heads being streamlined so as to reduce pressure losses.

In the most recent design the superheater elements are placed inside the evaporator tubes and therefore inside the combustion chamber. This gives a very compact and neat design as shown in Fig. 3. An evaporator tube with a superheater element partially withdrawn is shown in Fig. 5.

FIG. 5 SUPERHEATER ELEMENT PARTIALLY WITHDRAWN FROM EVAPORATOR TUBE

As previously mentioned, the overall efficiency of the supercharging set is of great importance. For the first boiler an impulse-turbine-driven blower was used, similar to those used for supercharging Diesel engines. The boilers are now fitted with reaction turbines having three to four stages (Fig. 6) and axial blowers (Fig. 7) which have been specially developed for this purpose. The overall efficiency is of the order of 83 (turbine) × 73 (blower) = 60 per cent.

With a view to reduction in weight, the gas-turbine casing is entirely welded, while the blower casing, Fig. 8, is built up of a blade-carrying cast-iron body and welded air chambers. Both machines have heavy shafts so as to run below the criti-

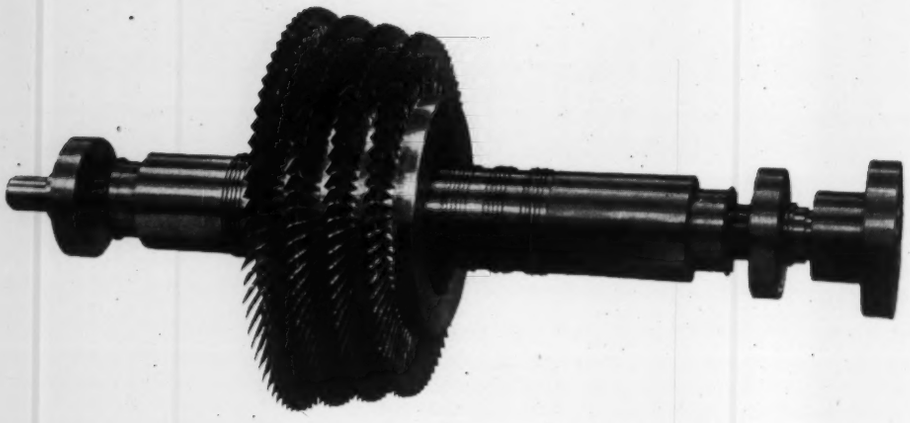


FIG. 6 FOUR-STAGE REACTION EXHAUST GAS-TURBINE ROTOR

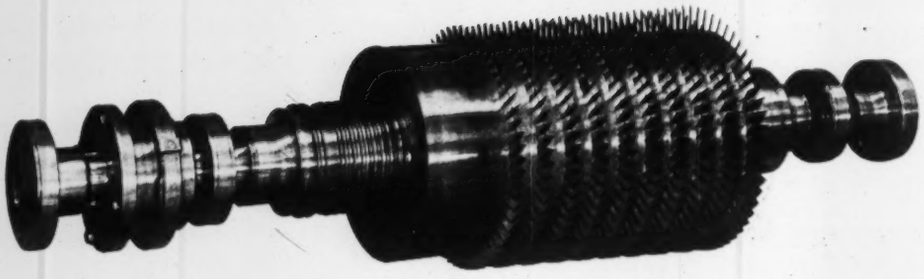


FIG. 7 ROTOR OF AXIAL BLOWER

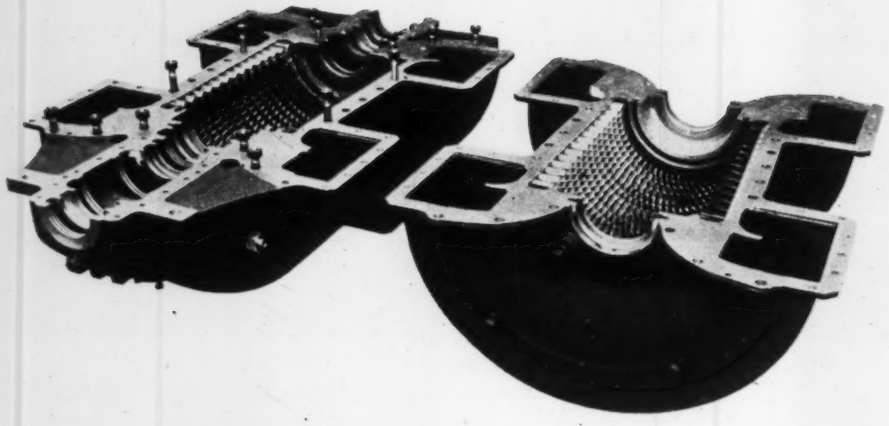


FIG. 8 AXIAL-BLOWER CASING

cal speed. As their speed varies proportionately with the load, they must be able to run continuously at any given speed between no load and full load.

The gases flow along the tubes of the preheater in the same manner as they do in the superheater. The elements of the preheater are therefore of similar design to those of the superheater and are shown in Fig. 9.

The automatic governing system is shown in Fig. 10. In principle the system is similar to that employed by Brown Boveri on their turbines for the last 20 years. The different devices for maintaining the feedwater level, governing the amount of oil and air, are shown, respectively, by *A*, *B*, and *C* of Fig. 10. An oil pump, connected to the motor driving the circulating pump already mentioned, supplies oil through the pipe 13 to the different governors. A plug 12 reduces the pressure in a variable degree according to the position of a leak-off valve 14. In *A* the position of this valve is governed by a water column acting against a spring, so as to keep the water level constant by varying the pressure beneath the piston 15 which governs the feed valve 2.

In the governing system *B*, regulating the amount of fuel oil, the leak-off valve 14 is governed by the pressure of the

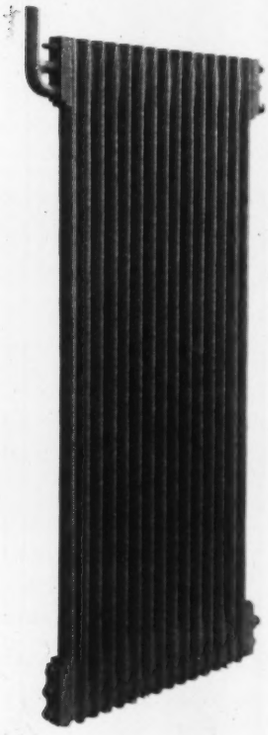


FIG. 9 PREHEATER ELEMENT

steam in such a way that with a falling steam pressure the valve is shut so as to raise the oil pressure under piston 16, thus opening the fuel valve 4.

The governing system *C* tends to establish a constant ratio between the amount of fuel and the amount of air; both the fuel valve and the air valve work on the same leak-off valve 14, and maintain their relative positions as long as the ratio of the two is constant. Any deviation from this ratio displaces valve 14 with a corresponding change in the oil pressure beneath the piston 17, adjusting the power of the auxiliary drive which may be an electric motor or a turbine.

If, for instance, more fuel oil is introduced owing to a fall in steam pressure by the system *B*, the auxiliary motor accelerates the supercharging set so as to get more air through. This is only necessary until stable conditions are again established by the increased pressure and temperature at the gas turbine, with a corresponding increase of power from that unit.

PERFORMANCE

Owing to the small amount of material taking part in heat transmission and to the small water-storage capacity, which has been purposely kept down to a minimum, the boiler can be set to work in an unusually short space of time. Fig. 11 shows how steam pressure, temperature, and quantity can be raised to full-load conditions in less than 5 min. The same applies to load variations, which are so rapidly dealt with by the automatic governing system that variations from half to full load and vice versa take only about 20 sec, as shown in Fig. 12. Even when full load is cut out suddenly, no blowing off occurs.

SPECIAL FEATURES

Pressure Firing. The combustion air and, with gas firing, the fuel also, are compressed by a blower and forced into the combustion chamber at a pressure of 28 to 50 lb per sq in abs and burned at this pressure. The pressure drop of the flue gases in pressure firing produces turbulence in the combustion-air mixture and imparts velocity to the flue gases, while a large part is absorbed in the gas turbine which drives the blower.

Gas Turbine. The energy required to drive the gas turbine is derived from the flue gases and is returned, minus radiation and bearing losses, entirely to the boiler by means of the work done in the blower in the form of heat given to the combustion air. This makes possible pressure firing with practically no external-power requirements. The power of the gas turbine is about 20 to 25 per cent of that provided by the boiler. This work is, however, internal, and for the aforementioned reasons is not noticeable externally. Due to the compression the air is heated to about 250 to 330 F and the blower thus replaces the air preheater.

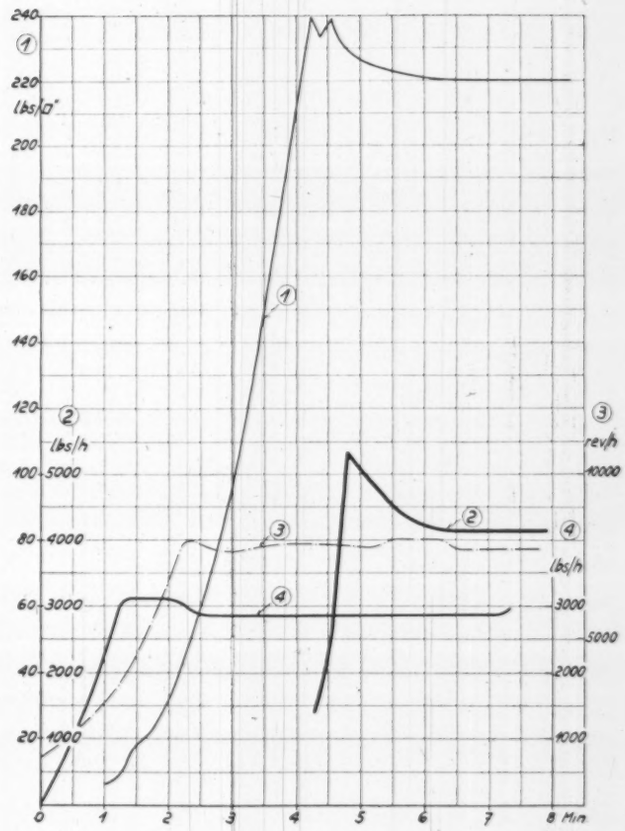


FIG. 11 STARTING CURVES OF A VELOX STEAM GENERATOR

(1 = steam pressure, lb per sq in.; 2 = evaporation, lb per hr; 3 = revolutions of blower and gas turbine, rpm; 4 = fuel consumption, lb per hr.)

High Flue-Gas Velocities. The velocity of the flue gases in the evaporator tubes is about 650 ft per sec and more, and in the superheater and feedwater heater in the region of 330 ft per sec. Very high velocities are also maintained in the burner in order to obtain adequate turbulence and a good mixture of air and fuel.

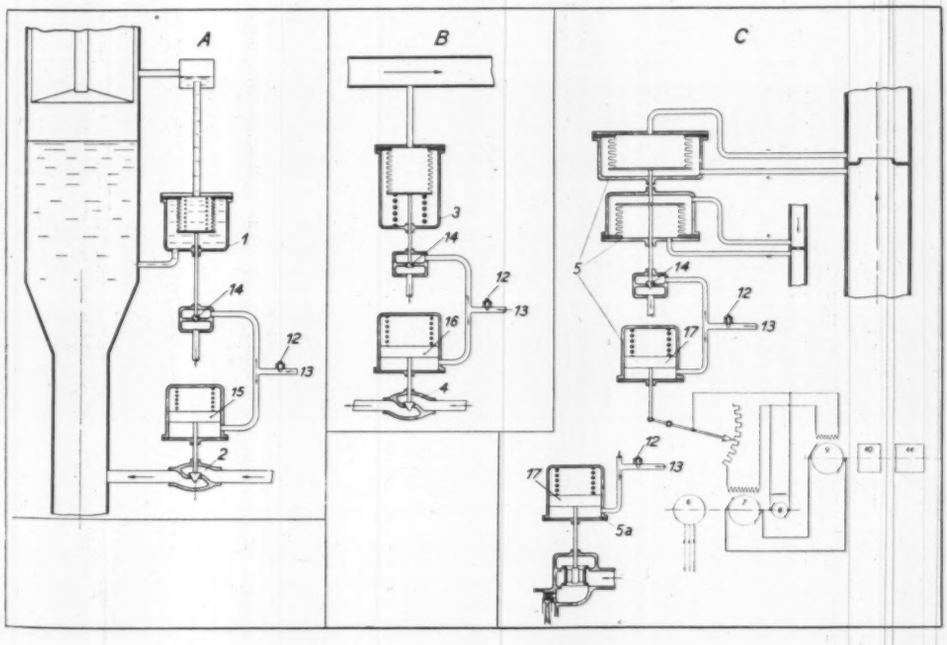


FIG. 10 DIAGRAMMATIC OUTLINE OF AUTOMATIC GOVERNING SYSTEM

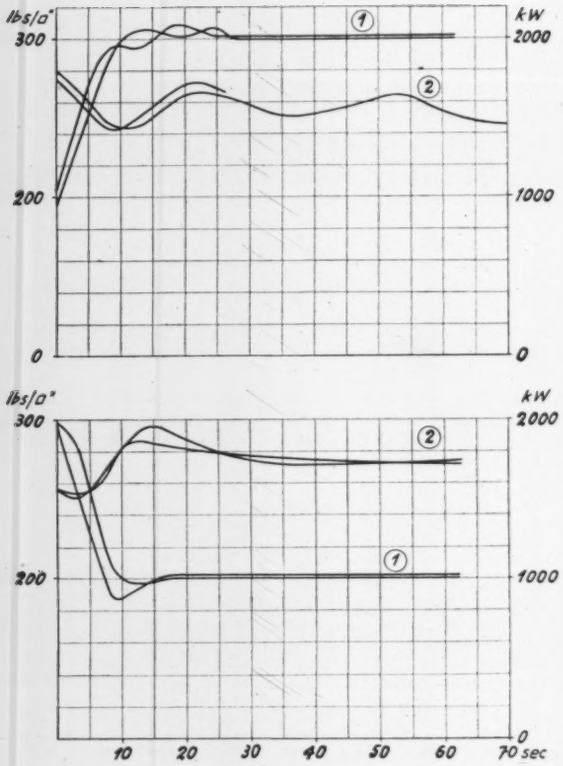


FIG. 12 VARIATION IN STEAM PRESSURE WITH THROWING ON AND OFF OF LOAD
(1 = load; 2 = steam pressure.)

Large Heat Transmission. The heat transmission by radiation resulting from the high pressure and high combustion temperature and the heat transmission by convection resulting from the high pressure and high velocities amounts to as much as 110,000 Btu per sq ft per hr at the walls of the evaporator tubes and inner heating tubes of the evaporator part, which corresponds to an evaporator output of 100 to 130 lb of steam per hr per sq ft of heating surface. The heat transmission in the preheater is also considerable, being about 10 to 20 times that of an ordinary boiler.

High Combustion-Chamber Outputs. As a result of combustion under pressure and the good mixture which is formed, for which purpose special burners have been evolved, combustion-chamber outputs up to 900,000 Btu per hr per cu ft are obtained, so that the combustion spaces need to occupy only one-tenth or even less of the space required for the combustion chamber of an ordinary boiler. These high combustion-chamber outputs are obtained with a minimum excess of air.

Forced Water Circulation. By means of a circulating pump high flow velocities are also achieved on the water side of the heating surfaces. The quantities of water in circulation are always 10 to 20 times greater than the quantity of water to be evaporated. The water capacity of the boiler is equal to about one-seventh to one-tenth of the maximum hourly steam quantity and thus is high enough to accommodate any sudden load without creating a disturbing change in pressure before the automatic governor can operate.

Mechanical Separation of Steam. The circulating pump gives the circulating water a sufficient pressure head to impart a high velocity to the steam and water mixture which is forced through nozzles into a vertical drum where separation of the steam and water takes place by centrifugal action. The separating capacity of this centrifugal separator is about 100 to 200 times greater than that of normal drums.

Completely Automatic Governing. Water level, fuel supply, and combustion air are all automatically regulated. Oil under pressure is used to convey the governor impulse to the pistons of the regulating valves. The governing is direct and of a precision hitherto unknown in boiler construction and only otherwise associated with internal-combustion engines. All governor elements can be influenced by hand, but during service the governing is effected entirely automatically.

Absence of Brickwork. Protection against the radiated heat or against contact with the hot gases is entirely by means of metallic heating surfaces. There is no brickwork to be destroyed by heat or rapid changes of temperature. Due to the small overall dimensions of the Velox boiler, radiation losses are considerably reduced.

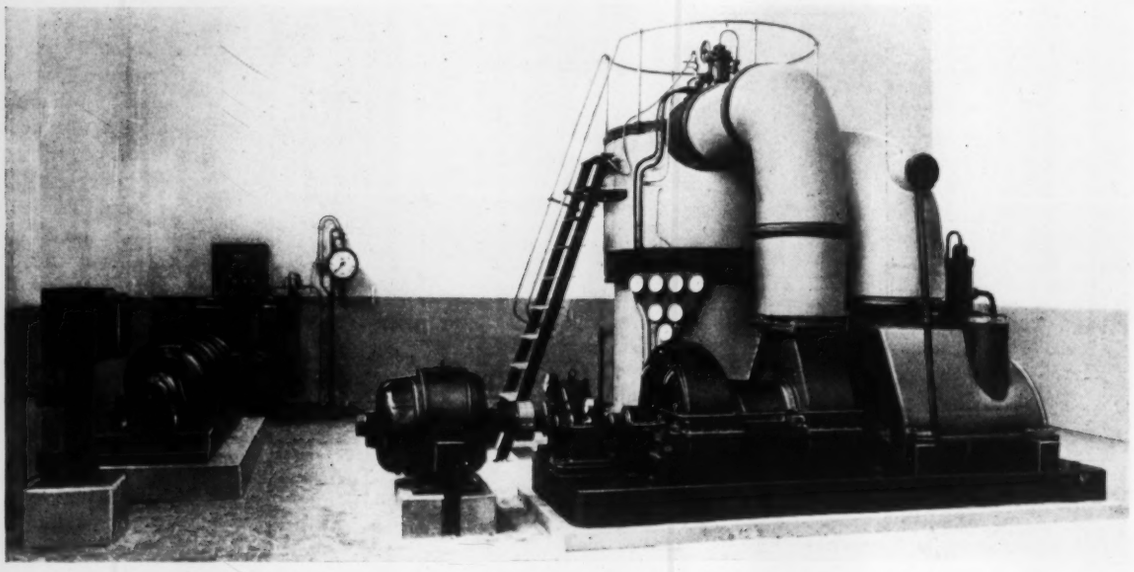


FIG. 13 VELOX POWER PLANT WITH SELF-CONTAINED SUPERHEATER

ADVANTAGES

Higher Efficiency. With oil firing and for stationary and merchant-marine boilers the thermal efficiency, that is, the degree of heat utilization, amounts to 94 to 96 per cent. The plant efficiency, including all auxiliary machinery except the boiler feed pumps, is 90 to 93 per cent. For gases of poor quality or for naval and locomotive boilers, which, on account of further reduction in weight have smaller preheaters, the efficiency is 2 to 3 per cent lower. The efficiencies remain practically constant from one-fourth to full load. All efficiency figures are based on the lower calorific value of the fuel.

Immediate Automatic Adaptation of the Firing and Feedwater to Suit Steam Requirements. Depending upon the kind and size of the auxiliary and governing motor, in the short time between 12 and 40 sec the load can be increased from one-fourth to full load without any appreciable pressure drop and unloading can occur over the same range without blowing the safety valve.

Rapid Starting. As a result of the small masses involved, the absence of refractory brickwork, and the positive supply of fuel and combustion air, the Velox boiler can be brought from a cold condition up to full load in 4 to 8 min, depending upon the size and loading capacity of the auxiliary motor.

Small Space Requirements. The necessary floor space, including adequate room for operating and erecting purposes, required, for example, for a boiler rating of 20 tons per hr is about 27 sq ft per ton; for 50 tons per hr, 16 sq ft per ton; and for boilers for warships, e.g., 60 tons per hr, 5 sq ft per ton.

The most important advantage of the small amount of space required is the possibility of a compact arrangement of boiler and prime mover, whereby steam lines, pipe fittings, and other accessories can be dispensed with, the whole installation being simplified and the boiler house completely eliminated.

Small Weight. The weight of the complete boiler plant, including all auxiliary machinery, depending upon the output, is for land installations 1.2 to 2 lb per 1000 lb of steam, for cargo vessels and locomotives 1.0 to 1.8 lb per 1000 lb of steam, and for warships and "small boilers" 0.6 to 1.2 lb per 1000 lb of steam.

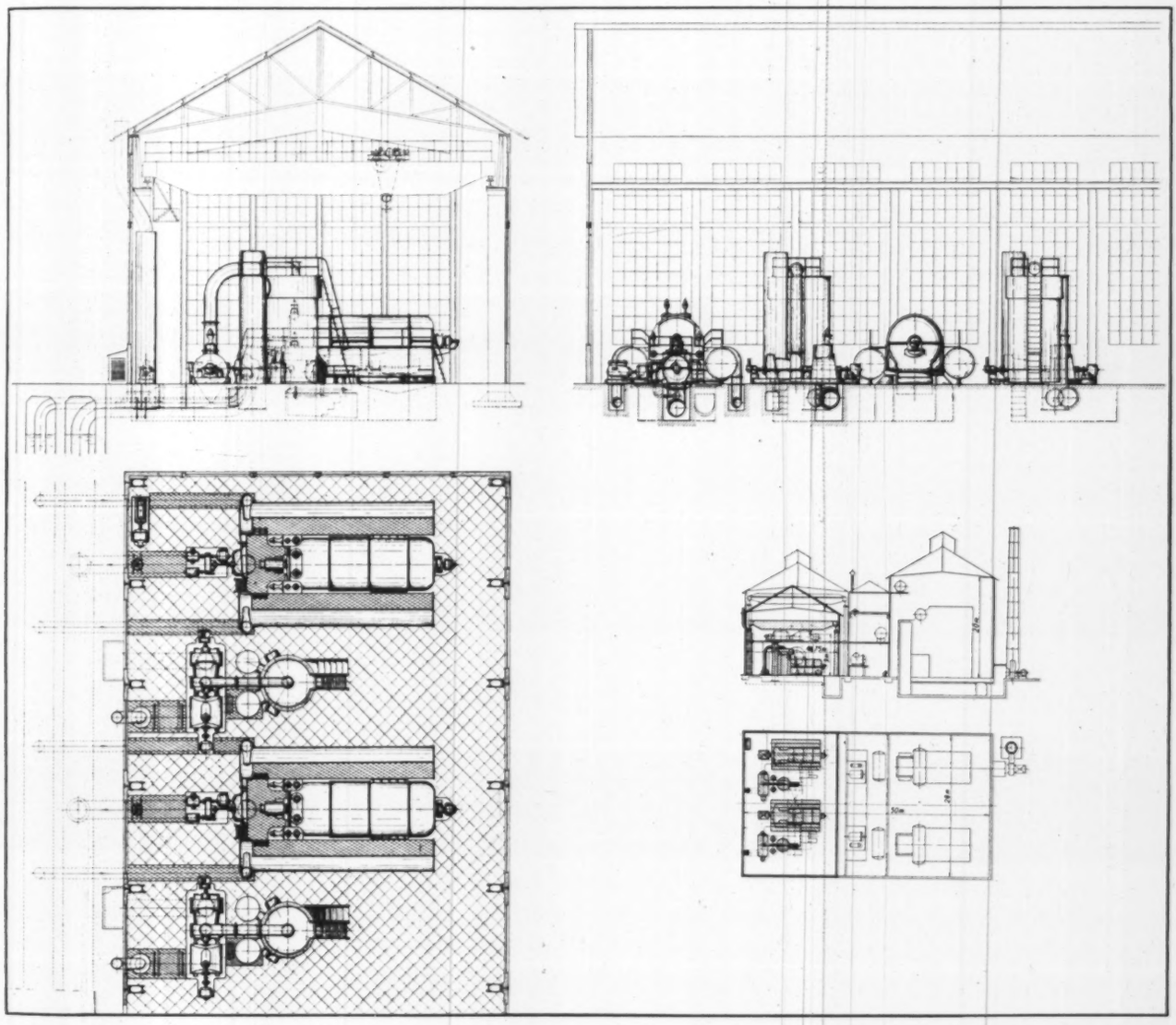


FIG. 14 VELOX POWER STATION WITH TWO 15,000-KW UNITS

(Steam generator and turbine form one unit and boiler house, with long pipe lines, is eliminated. In lower right-hand corner is a comparison with an ordinary power plant. The Velox plant, shaded, is superimposed.)

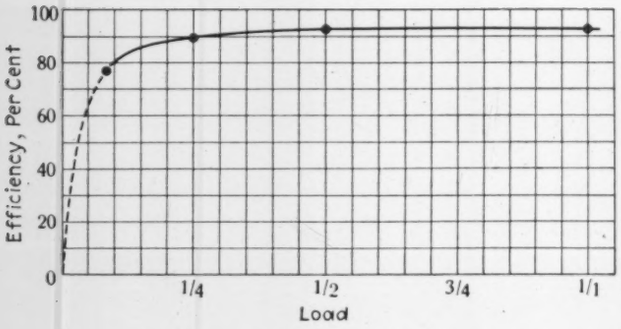


FIG. 15 EFFICIENCY OF VELOX BOILER

Rapid Erection on Site. The boiler can be completely erected and tested in the shops of the manufacturer so that erection on the site takes only a short time. It requires little foundation and no brickwork. Due to the comparatively high exhaust-gas velocities which are admissible, it is possible to keep exhaust-gas piping and flues small.

II—APPLICATIONS OF THE VELOX STEAM GENERATOR

The aforementioned features and advantages of the Velox steam generator make it attractive for a number of applications on land and sea.

POWER STATIONS AND INDUSTRIAL SERVICES

For power stations and industrial services in places where gaseous or liquid fuel can be obtained cheaply the Velox boiler has attractive possibilities. When comparing fuel costs, however, it must be considered that the Velox boiler has a higher efficiency than other boilers (especially those that are coal-fired) and the possibilities of governing and rapid starting which it offers almost completely eliminate the losses resulting from partial loading and stand-by periods.

The initial cost of the power station will be considerably lower than that of one with ordinary boilers because of reduced costs for the building, foundations, cranes, and piping.

The Velox boiler offers above all the possibility of a revolutionary change in regard to power-station construction. Boilers and turbines need not be two independent units separated from each other in regard to space and their attendance and operation, but can be united in one organic whole. The boiler can be mounted in the engine room in the immediate proximity of the turbine. The pipe lines become shorter, various fittings are eliminated, and as the attendance required for the boiler and turbine is exactly of the same kind, it can be provided by the same attendant. The plant can be still further simplified because certain devices which have been introduced in power-plant practice in order to effect an economy can be dispensed with without impairing the efficiency of the plant. Thus the air preheater is replaced by the turbo-blower which heats the air through compression, and in place of high feedwater preheating by means of multistage steam extraction there is the less expensive flue-gas economizer, which may be combined with single-stage steam extraction. For super-high-pressure plants which require an intermediate superheater, the Velox boiler affords special advantages on account of its compactness and high rate of heat transmission.

Fig. 13 shows a Velox steam generator built for a plant in Spain. Fig. 14 shows an installation in which steam generators and turbines are one unit in one room.

PEAK LOADS AND RESERVE POWER

For peak loads and reserve power the fuel costs are not important because such plants are generally in service only a few hundred hours a year. However, the possibility of getting steam in a short time is of paramount importance. In most cases it will suffice if the full quantity of steam is available in about 4 to 8 min. If, in cases of emergency, the approach of which can be foretold (storm or fog), the boiler has to be ready to give steam in less time, it can be heated up in a few minutes and stay so without fire, ready to take full load in a few seconds. The Velox boiler thus replaces the accumulator formerly used in such cases. Compared with Diesel engines it has great advantages in that it occupies much less space, has a lower first cost, can be built in any size, can burn cheaper oil, and can act as a reserve for the other steam boilers.

Test results on plants of the Société de Gaz et d'Electricité du Sud-Est, Toulon, France, for the Haifa power station of the Palestine Electric Corporation, Ltd., and for the Mondeville station of the Société Métallurgique de Normandie are given in Table 1 and Fig. 15.

In the efficiency figures the supplementary power of the auxiliary motors was accounted for as heat transmitted to the system with the overall efficiency of the plant including boiler and turbine. Fig. 16 shows the Toulon steam generator erected on site.

IRON AND STEEL WORKS

In steel works the Velox boiler with steam turbine may be used as a substitute for gas engines. A gas-engine plant with six engines of 3500 kw each and two 5000-kw waste-heat turbo-generators, i.e., 31,000 kw total, can be replaced by two Velox steam generators and a steam turbine of 30,000 kw output, which take the same space as that occupied by one of the gas engines. Such a steam plant can, owing to its high efficiency at all loads, advantageously compete with the gas engine with steam pressures around 600 lb and temperatures of 800 F. The dust content of the gas used for Velox steam generators can be the same as, or slightly higher than, that of the gas used for gas engines.

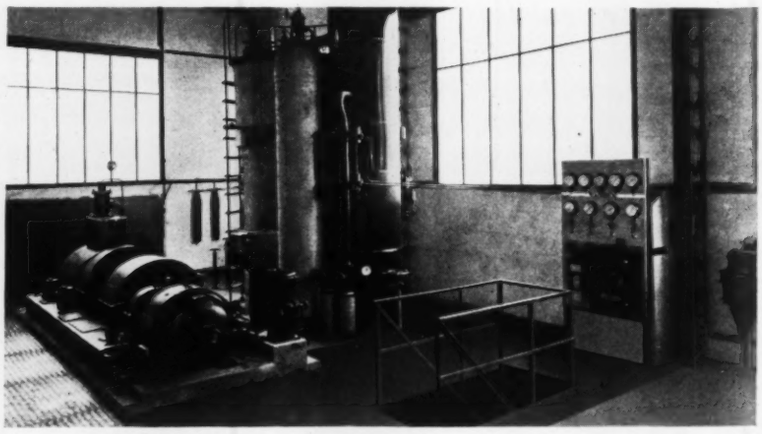


FIG. 16 VELOX BOILER WITH EXTERNAL SUPERHEATER, TOULON, FRANCE

(The steam generator is in service every evening as a peak-load boiler, and in summer serves with a turbine as a reserve plant for a distant hydraulic power station. The evaporator and turbine run idle and take over the service instantaneously when any disturbances occur.)

A small plant of this kind for the Société Métallurgique de Normandie, Mondeville, France, is shown in Fig. 17. The test results are reported in Table 1.

A further application for the Velox principle in steel works is afforded by blast-furnace air heating. Due to the availability of high-quality steel, capable of withstanding high temperatures, it becomes possible to use blast-furnace air heaters of metal in which both the heating gas and the air to be heated are made to flow past the heating surfaces with a very high velocity according to the Velox principle. However, as the temperature of combustion would prove to be by far too high for the air-heating surfaces, a Velox steam generator is used as a combustion chamber and is so dimensioned that the gases are cooled to an appropriate temperature. The steam produced by this boiler is used for driving the blast-furnace blower and to supply an auxiliary steam turbine, assisting the gas turbine which drives the blower of the Velox steam generator. Owing to the supplementary resistance of the air heater, this blower has to give a higher pressure than in a normal Velox plant, so that the gas-turbine output is insufficient to drive it. Such a plant has not yet been built.

CENTRAL HEATING PLANTS

The small space requirements, high economy, rapid starting, and quick regulation, but above all the cleanliness, quietness, and freedom from smoke, make the Velox boiler suitable for heating plants. The plant becomes especially simple when used for producing hot water, as in this case the steam separator and superheater can be dispensed with.

Such plants have been supplied for the University Centers of Madrid and Rome, for the Swiss Federal Institute of Technology in Zurich, and for the State Hospital in Aarau, Switzerland, with a total of six boilers. In three of the four plants the Velox steam generator runs in parallel with coal-fired or electric boilers, being especially used for peaks and small loads.

MERCHANT VESSELS

The most important field of application for the Velox boiler is doubtlessly the ship. The small space requirements of this boiler and its low weight and high efficiency are of most value here, and the fact that it is essentially an oil-burning boiler is no drawback in most cases. In comparison with the Diesel engine the Velox steam generator has the advantage that every kind of oil can be used and there is no restriction as to the use of the more expensive gas and Diesel oils. The fuel consumption of the Diesel engine is, of course, lower than that of a Velox steam-turbine installation. The difference in price between Diesel oil and bunker oil is, in many countries, greater than the difference in fuel consumption, so that the fuel costs for a Velox are generally lower than those for Diesel engines. The Velox steam-turbine plant is also more favorable in regard to weight, except for long voyages where the excess fuel oil equalizes the weights in about 40 days steaming. The weight of a Velox steam generator is on an average one-fifth that of the ordinary oil-fired water-tube boiler, and its space requirements, even compared with the most modern marine boilers, are less than half. Of great importance are its small height and the smaller dimensions of the flues and funnels.

With existing plants having a larger number of boilers it is generally possible to replace one existing boiler by a Velox which takes the output of all the other boilers. By means of such a substitution the power range and economy of old ships can be considerably increased, and even more so if at the same time the steam pressure and superheat are increased and the additional heat drop is used in a supplementary high-pressure turbine which may drive through existing gear. In new ships

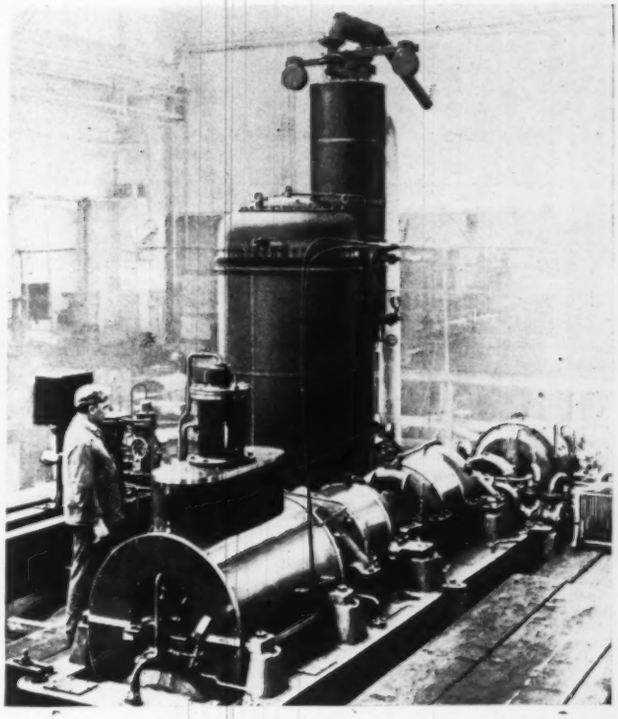


FIG. 17 VELOX BOILER FOR BLAST-FURNACE GAS (ON TEST BED)
(Output 13 tons of steam per hour at 440 lb per sq in. gage and 797 F. Velox boilers fired with blast-furnace gas have two blowers, one for gas and one for air. The mixture of gas and air takes place directly in front of the burner. The axial thrust of the blowers is balanced by the opposed arrangement. The gas turbine is double-ended.)

the Velox enables a more favorable arrangement of machinery, higher power, and more loading space for cargo and fuel to be obtained.

WARSHIPS

In warships of ordinary design the full steam output is obtained by forcing the boilers to about three to four times the amount which such a boiler would normally give if otherwise applied. The efficiency of such boilers, therefore, decreases when the load increases with increasing exhaust temperature of the flue gas. The difference in weight and space requirements of the Velox boiler, when compared with such forced boilers, is thus not so considerable as is the case when compared with boilers which have to operate at highest efficiency. However, the weight and space requirements of the Velox boiler, as developed for warships, remain considerably below those of the lightest type of marine boiler.

The weight of a complete boiler plant for a warship of smaller size is under 1 lb per lb of maximum steam production. Steam generators for 60 tons of steam per hr and more weigh, including water and oil for lubrication and governing, less than 0.8 lb per lb of steam per hr.

The small space requirement enables two Velox boilers of 60 to 75 tons per hr each to be accommodated in a standard torpedo-boat profile of 23 to 26 ft width and 18 ft in height between two bulkheads 23 ft apart. In submarines, the small masses, the possibility of rapid cooling by running cold air through the boiler, and the small dimensions of the exhaust pipes enable the time required to prepare for submerging to be reduced to an extent hitherto only to be obtained with Diesel engines.

A fundamental difference between the Velox boiler and navy boilers is that full load can be maintained continuously for any length of time with the same high efficiency as on part

TABLE 1 ACCEPTANCE TESTS ON VELOX STEAM GENERATORS

Plant	Toulon Power Station, Soc. de Gaz et d'Electricité du Sud-Est				Haifa Power Station Palestine Electric Co.	Mondeville Power Station Soc. Métallurgique de Normandie.			
Testing Authorities:-	The tests were performed on July 31, and August 1, 1934 by the "Association des Propriétaires d'appareils à vapeur et électriques du Sud-Est".				The tests were performed on August 2, 1934 in the testing shop of the builders, by Prof. Dr. A. Stodola, Zürich.	The tests were performed on January 25, 1934 by the "Soc. Métallurgique de Normandie" in Mondeville.			
Test	1	2	3	4	1	1	2	3	4
Load	minimum	1/4	2/4	4/4	Full load	Full load			
Fuel	Masut of 9669 kcal/kg				Masut of 9517 kcal/kg	Blast furnace gas			
Fuel consumption kg/h	244	498	1001	1902,8	2842	11798	11871	11350	11813
						(dry gas)			
Flue gas temperature at exit of economiser °C	82	77,4	96	113	128,7	112,6	108,2	114,1	116,3
Water and steam:-									
Quantity of steam generated kg/h	2982	6575	13150	24480	33700	11287	11687	10934	11098
Live steam pressure at exit of superheater kg/cm^2 abs	19,14	19,09	18,65	17,30	28,2	14,28	14,54	14,31	14,61
Temperature of steam at exit of superheater °C	295,8	313,0	346,4	372,3	461,8	422,95	416,91	425,45	433,39
Feed water temperature °C	45,3	39,5	42,2	48,3	55,4	35,75	36,33	40,36	41,02
Power required by auxiliary machines:-									
Input at terminals of auxiliary motor of blower set kW	7.7	13,9	11,1	32,8	— 5,2	118,5	123	133,5	116,75
Total power for auxiliary machines, excluding feed water pump kW	46,8	54,3	49,2	78,7	50,5	155,23	159,87	171,07	154,14
Measured plant efficiency *) %	77,0	89,3	93,4	93,0	92,6	89 **)	89,5	86,6	86
Remarks from test reports	The results show that all the guaranteed efficiencies have been attained and even far exceeded. The great adaptability of the blower and the good automatic regulation were particularly noticeable. Entire absence of smoke during all tests.				The entirely automatic regulation showed with large variations in load a steady transition to the new state of equilibrium. Starting from the prewarmed condition with immediate generation of steam, full load could be attained in 4 minutes. A promising field of application is opened to the Velox boiler even when high oil costs do not allow for continuous service.	The results are very satisfactor. During tests no imperfections in operation, in the machines or governing apparatus were noticed.			

*) $\eta_A = \frac{\text{Heat in Steam - Fuel preheating - 4000 x kW input of all auxiliaries.}}{\text{Quantity of fuel x lower Calorific Value.}}$

**) On account of the mixtures having poorer heating valve and also due to higher suction temperatures, larger blower powers are required than with oil-fired boilers.

load. This efficiency amounts to between 88 and 90 per cent, compared with 75 per cent or less obtained with a forced ordinary boiler. The Velox boiler operates entirely automatically, the exhaust gas is completely invisible even at maximum output and has a low temperature. When steam is available from one boiler only, supplementary boilers can be brought from cold up to full load in less than five minutes.

By taking full advantage of the technical means offered by the Velox boiler, war vessels of hitherto unforeseen striking power may be built.

For obvious reasons no information about Velox plants in warships is available except the fact published in British papers, that one unit is built for the British Navy by Yarrow and Richardsons Westgarth, the former building the boiler proper, the latter the gas turbo-blower and other auxiliaries.

LOCOMOTIVES

Space requirement, weight, and efficiency are also of paramount importance for locomotives. The wheelbase, axle loading, and gage determine the dimensions of the boiler, and for the ordinary locomotive boiler the maximum output is thus fixed. By means of the Velox boiler the output can be considerably increased. Due to its small weight the weight of the locomotive need not be greater than is essential in order to maintain the necessary adhesion, so that all superfluous running wheels can be dispensed with. The small amount of space required enables the boiler and the auxiliary devices to be easily accommodated in the chassis in such a way that adequate room is left over for driving and attendance. The driver's cab, for instance, can be situated in front and the entire locomotive mounted in a streamlined body. The automatic governing of the boiler simplifies the attendance and the rapid steam production and adaptability to varying loads enable much shorter starting times and more rapid acceleration to be obtained than is the case with the ordinary locomotive boiler. By substituting a Velox generator for an ordinary locomotive boiler on an existing locomotive it is possible to obtain higher speeds and greater running ranges without altering the driving mechanism. A transformation of an existing locomotive to 2400 hp and 100 miles per hour has been ordered.

The Velox can also be advantageously used on rail cars and is especially favorable in competition with Diesel rail cars. For smaller powers (up to 1000 hp) the plant is equipped with air-cooled condensers.

"THE COMET"—HIGH-SPEED TRAIN

Structural, Mechanical, and Aerodynamical Considerations in Its Design

By KARL ARNSTEIN

GOODYEAR-ZEPPELIN CORPORATION, AKRON, OHIO

I—DESCRIPTION OF THE TRAIN

THE "COMET" was designed to meet the requirements of the New York, New Haven, and Hartford Railroad for fast service over the short run between Boston and Providence with one intermediate stop and rapid turn around, and at the same time to provide, also at high speeds, a degree of riding comfort comparable to the best attained at present ordinary speeds.

These requirements dictated the use of a power plant (Fig. 1) in each end to obviate the necessity of turning the train at either end of the run; the application of power to four axles for acceleration reasons; a reduction in weight and rolling resistance to obtain rapid acceleration; a good aerodynamic shape and finish to permit relatively high speed with a small power plant in order to keep down weight and reduce operating expenses; and a new type of car construction to obtain the reduced weight without sacrificing safety and to obtain improved riding qualities and comfort. The welded-steel end sill for connecting the cars which make up the train is shown in Figs. 2 and 3.

Each power plant consists of a 400-hp Diesel engine directly connected to a railway-type generator and integral exciter. Two 200-hp traction motors (Fig. 11) are located on the end trucks directly under each power plant. The engine bedplate, Fig. 4, is a welded chromansil steel composite structure forming the lower crankcase of the engine, tanks for lubricating and fuel oil and water, and the body bolster for the power truck.

While reduced weight was considered of great importance in order to obtain the required acceleration, nevertheless, primary consideration was given to structural strength and rigidity for protection of the passengers and crew, riding comfort, and reduction in maintenance cost. Maximum strength with the allotted weight was therefore the keynote of the design, and a special type of car body was created to meet this requirement. This car-body design offers exceptional rigidity and also a high factor of safety and energy-absorbing qualities in case of collision or derailment. Figs. 5, 6, and 7 show details of the construction.

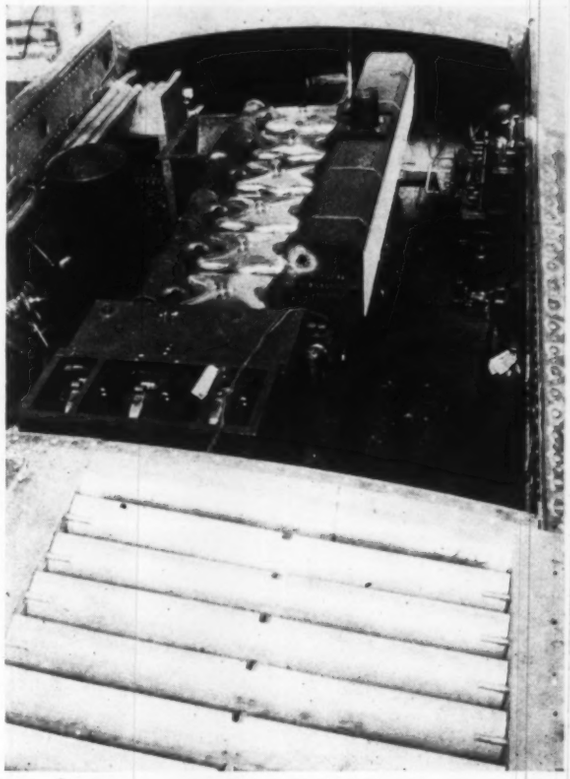


FIG. 1 LOOKING INTO THE ENGINE ROOM THROUGH HATCH OPENING WITH HATCH COVER REMOVED

The floor of the cars is extremely low, only 32 in. above the rail top. A comparison of the cross-sectional dimensions of a conventional chair car with those of *The Comet* is given in Fig. 8. Because of the low floor height it was not necessary to reduce the cross-section of the passenger compartments in order to reduce the frontal and lateral aspect area and thus minimize air-resistance and side-wind forces. The compartments have a standing height of 7 ft 10 in., a width of 9 ft 4 in., allowing room for two 43-in. double seats and a 26-in. aisle, and doors of standard height of 6 ft 8 in. The center of gravity of the train including the power plants is about 50 in. above the top of the rail.

The outside of the train is smooth with well-rounded corners, and the bottom is covered and cut out only in the vicinity of the trucks. Only two steps are required to enter or leave the train. These steps, Fig. 9, together with their corresponding doors on both sides of centrally located vestibules, are operated by electrically controlled air engines, and in closed position they produce an unbroken smooth outside surface with the rest of the train. The large, fixed, double windows are set flush with the outside of the train. There are no exposed steps or grab irons to offer wind resistance. Even the rivet heads are of special design to give minimum height with full strength. Attention to these many details and the adoption of an aerodynamically acceptable shape at the ends has resulted in a train of reasonably low air resistance.

It was recognized that a new type of suspension between the car bodies and trucks would be necessary if comfortable riding were to be obtained, especially with the low center of gravity and higher speeds. This was accomplished by replacing the conventional elliptic springs with "shock absorbers"—coil springs with hydraulic damping to provide cushioning. The shock absorbers and their method of application practically eliminate the rolling motion of the car body and provide greater stability and damping of oscillations. Details of the trucks are shown in Figs. 10 and 11.

In addition to smooth riding characteristics the comfort of the passengers is also dependent upon the reduction in audible

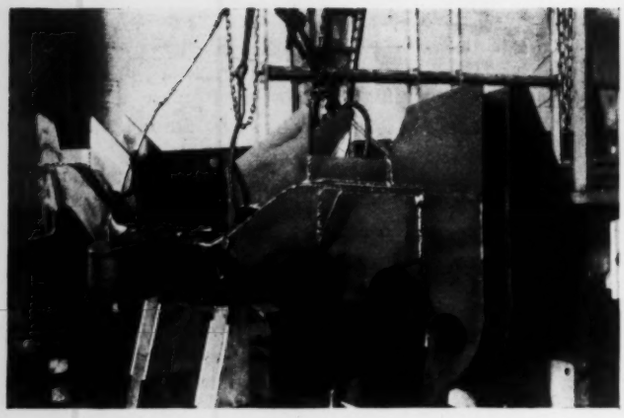


FIG. 2 WELDED-STEEL END SILL FOR CONNECTING THE CARS

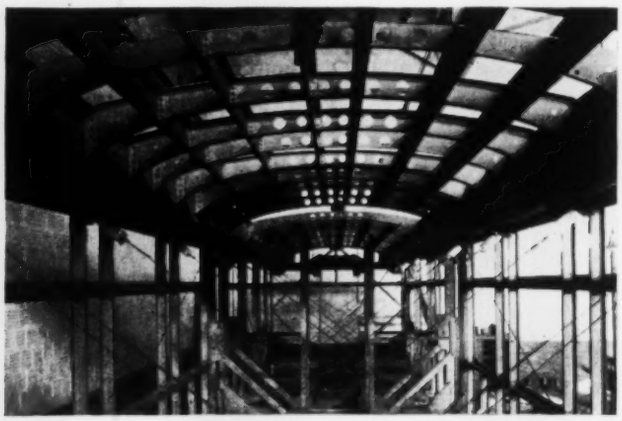


FIG. 5 CAR STRUCTURE SHOWING ROOF CARLINES

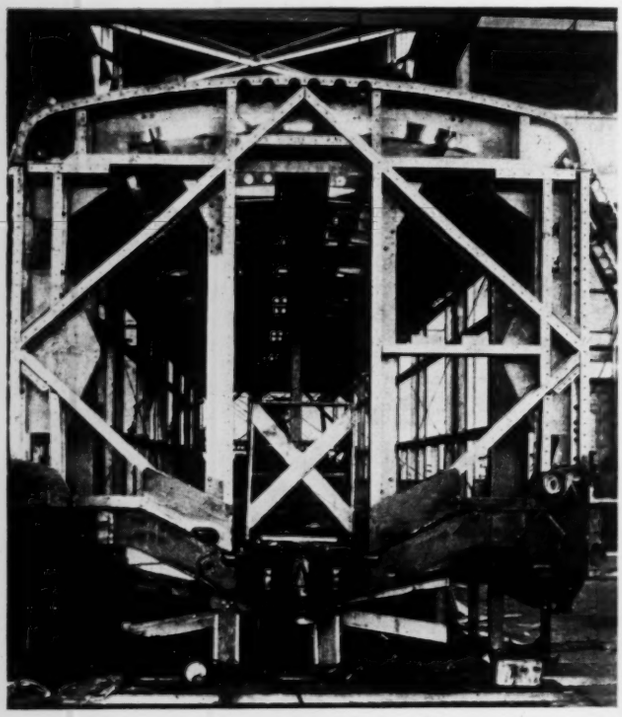


FIG. 3 CAR END BULKHEAD CONSTRUCTION

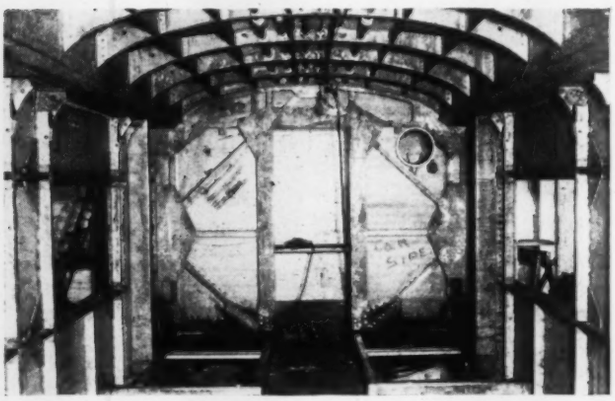


FIG. 6 CAR INTERIOR BEFORE INSULATION WAS INSTALLED

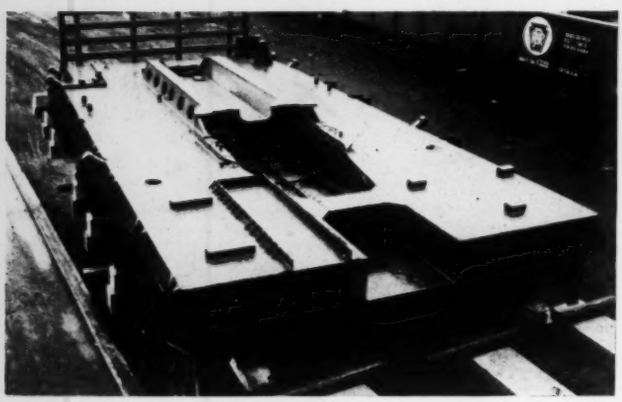


FIG. 4 WELDED-STEEL ENGINE BEDPLATE

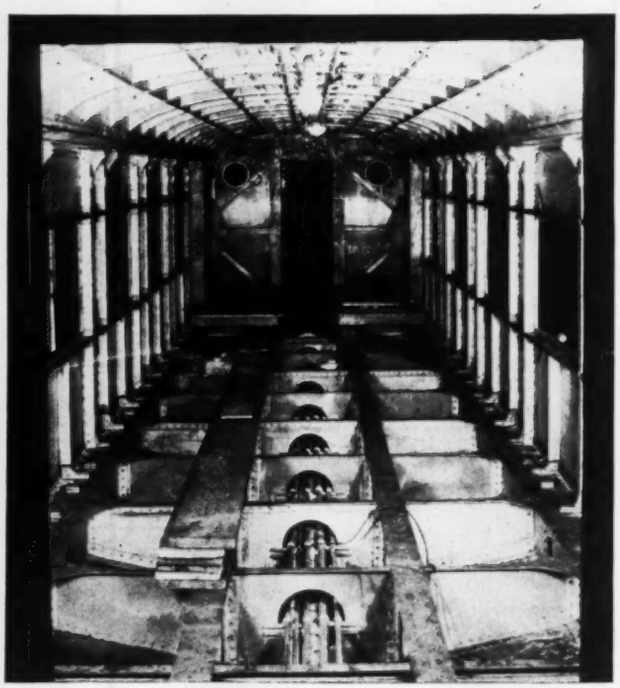


FIG. 7 DETAIL OF FRAME STRUCTURE, SHOWING STEAM, AIR, AND WATER LINES INSTALLED UNDER FLOOR

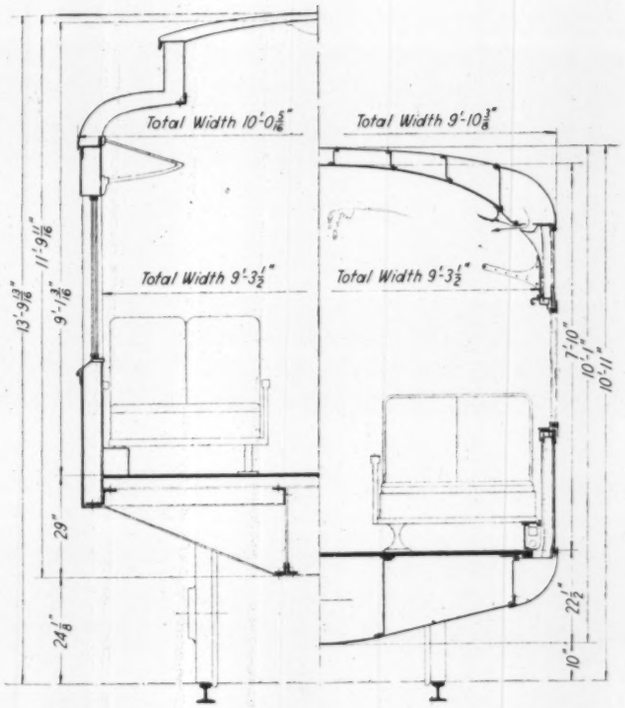


FIG. 8 CROSS-SECTIONAL DIMENSIONS OF A CONVENTIONAL CHAIR CAR AND "THE COMET"

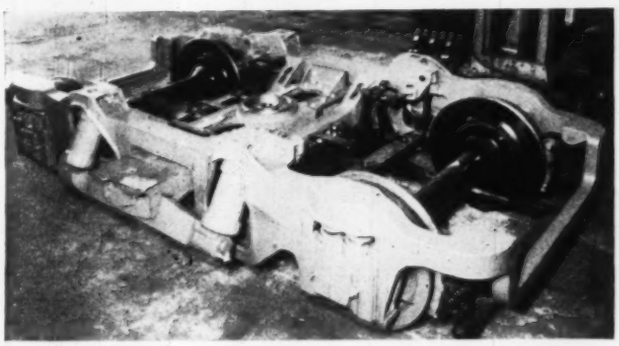


FIG. 10 ARTICULATED TRUCK WITH SHOCK-ABSORBER SUSPENSION

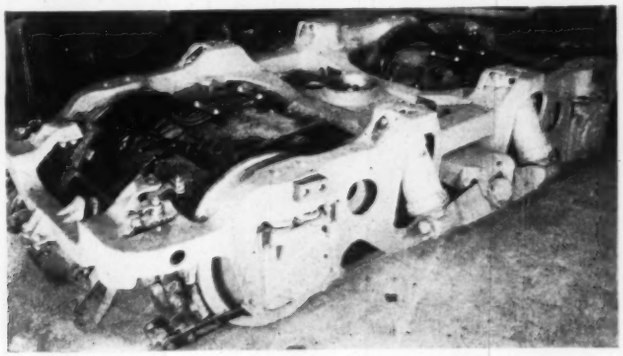


FIG. 11 POWER TRUCK WITH TRACTION MOTORS AND SHOCK-ABSORBER SUSPENSION

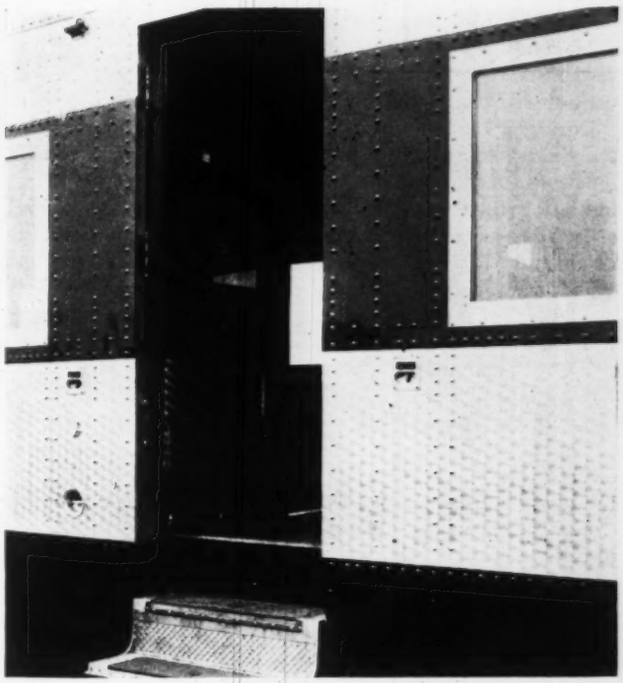


FIG. 9 DOOR AND STEP WHICH FAIR INTO SIDE WHEN CLOSED

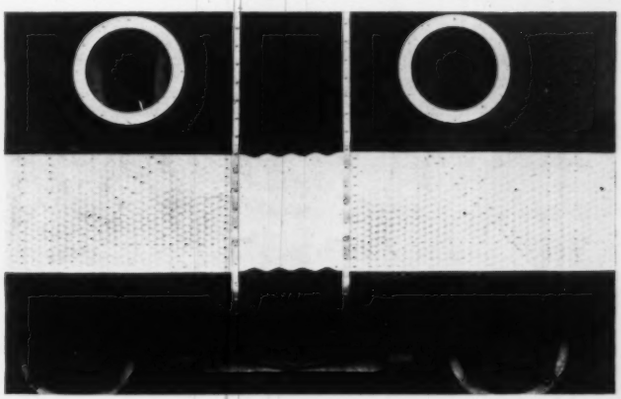


FIG. 12 RUBBER DIAPHRAGM BETWEEN ARTICULATED CARS

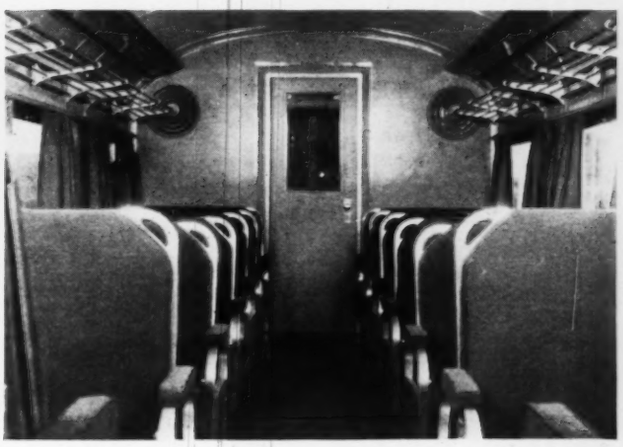


FIG. 13 INTERIOR OF ONE OF THE COMPARTMENTS

noise, the maintenance of fresh air at a reasonable temperature throughout the year, the provision of adequate light, comfortable seats, roominess, and an interior finish conveying warmth and cheerfulness.

During a careful investigation in the laboratory on the sound-deadening properties of various heat-insulating materials, it was apparent that the general principle of a blanket of heat-insulating material when covered with a continuous sheet offered a good sound-deadening medium. The cascade effect of air space between sound-deadening walls helped to reduce sound transmission. The final selection of the materials was based on the combination of sound deadening, heat insulation, weight, and fire resistance. A dense felt blanket, faced on one side with aluminum foil, was selected for general application. The uncovered face of the felt blanket was cemented to the inside of the car-body plating and to the interior wall. The air space between was packed with either four or six courses of crumpled aluminum foil. The heavy outside plating and the aluminum-covered plywood for interior finish also contributed to sound deadening. In the center part of the roof section in the region of the electrical conduits, glass wool between asbestos sheets was used, as it had the additional property of being fireproof.

Rubber was used extensively in the trucks to break up the direct metallic contact above and below the journal-box coil springs, around the center bearings, behind the bolster guide plates, and in the articulated truck side bearings. At the articulated points the cars are connected on the outside with a taut extensible rubber diaphragm, Fig. 12, to maintain the smooth, straight surface. A similar diaphragm forms the inner vestibule between the cars. The ends of the cars at the articulated connections are covered with sound-absorbing material. The combination of the diaphragms and the sound-absorbing material reduces the noise at the articulated points.

The ventilation system required much attention to detail. The system supplies 25 per cent fresh air continuously with the train running in either direction or standing still. The vestibules are used as air-mixing chambers. A careful series of experiments in the wind tunnel provided the necessary data to design the fresh-air intakes which would allow entry of air at all speeds and under various wind conditions. These intakes are located in the vestibule outside doors. The recirculated air enters the vestibule through louvers in the car bulkheads where it is mixed with the fresh air. The circulating fans, air-conditioning evaporators, and overhead heating coils are located above the ceiling in the vestibules. All air entering the fans is passed through filters located in the ceiling and is discharged over the cooling or heating coils to the upper structural booms of the car body. The outlets from these booms are so proportioned that good distribution is obtained throughout the length of the cars. Positive assurance of discharge of foul air is obtained by use of exhaust fans which discharge the 25 per cent out of each car through the washrooms and the end bulkheads into the space between the inner and outer rubber diaphragms. The discharge is thus protected from any effect of cross-winds and direction of movement of the train.

The air-conditioning system is of the freon-refrigeration type. Sufficient steam vapor coils are provided in the evaporator units to provide 25 per cent of the heating required. The remainder of the vapor heating is supplied from finned copper piping located at the floor and against the side walls. The boiler is located in one engine room.

The lighting of the coaches is indirect, with the troughs located at the sides of the ceiling. The trough is an extruded aluminum section lined with Alzac-treated reflector sheets. The lamps are 23-volt—S17 type—115 volt spaced on 10-in. centers. The amount of light at the reading level in the finished car is about 7 to 8 foot-candles.

In order to meet the quick turn around of the train the necessity of rapidly reversible seats dictated the use of walk-over type. These were specially designed for comfort. The seats are low, thus eliminating the need of the foot rest.

A substantial full-length baggage rack finished in aluminum harmonizes with the rest of the interior. Door closers are of the concealed type and the use of pivot hinges permits building the required anti-pinch feature into the doors. Fig. 13 is an interior view of one of the compartments.

The interior design is purely functional with emphasis placed upon simplicity. A limited number of tan colors, ranging from a light ivory tone of the ceiling to a rust (deep rich copper) color of the seat covering, combined with metal moldings and other hardware of natural silver satin finish, has been selected to create an esthetic appearance.

Safety has been given special attention and many features have been added. An efficient air-brake system will stop the

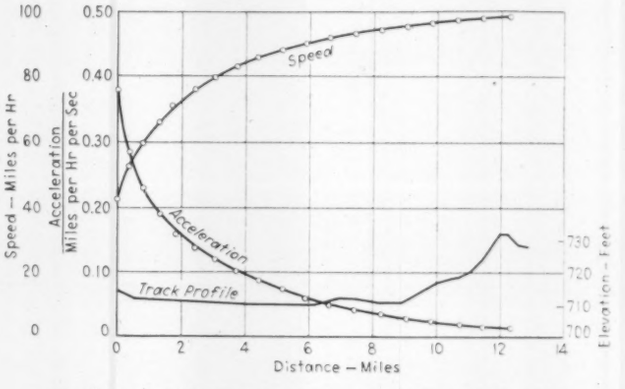


FIG. 14 ACCELERATION CHARACTERISTICS OF TRIAL RUN

train, in spite of the high speed, in less distance than that required to stop present-day passenger trains. The "decelakron" assures rapid but smooth stopping of the train. The self-lapping brake valve gives the engineer almost perfect deceleration control. The train cannot start before the air reservoir pressure is up to normal. It is equipped with "dead man" control designed to stop the train if the engineer becomes incapacitated. An emergency air-brake application automatically idles the engines, and if the lubrication system does not function properly, the engine will trip itself. The engineer cannot release the brakes when any door step is not closed. The steps cannot be closed while a person is on them. The doors cannot be opened when the train is making a speed in excess of 5 mph.

There were made, during the trail runs, many measurements of factors which controlled the performance of the train. It will be some time before the data are completely evaluated. A preliminary study, however, shows satisfactory agreement with the assumptions on which the performance had been predicted. As illustrative of the data acquired, the acceleration characteristics on one of the trial runs is given in Fig. 14. This run was made prior to final adjustments of the generators. The course was too short to reach top speed and a slight grade was hit near the end of the run. There was a slight cross-track wind. Since that date speeds in excess of 105 mph have been reached on level track.

[The second part of this paper, which will appear in a later issue, is devoted to the structural design and strength of the train and the mechanics of the train in motion.—EDITOR.]

A New Curriculum in
MECHANICAL ENGINEERING

By F. L. EIDMANN, W. A. SHOUDY, AND T. BAUMEISTER, JR.

DEPARTMENT OF MECHANICAL ENGINEERING, COLUMBIA UNIVERSITY, NEW YORK, N. Y.

THE American Engineering Council has recently completed a brief analysis of the professional activities of 172,146 who listed themselves as engineers under the last census. This analysis opened so many lines of thought that the U. S. Bureau of Labor Statistics became interested and is cooperating with the Council and the several national engineering societies in a profession-wide survey, the results of which should be available this year.

This preliminary survey lists 78,813 civil, 44,752 electrical, 40,409 mechanical, 4738 mining, and 3434 chemical engineers. Although the census classification is open to error because some men claim the title of engineer who are not entitled to it and others are in executive or other positions not definitely labeled engineering, this analysis is the most comprehensive that has thus far come to light.

The distribution in industry of the five types of engineers is very interesting. The major activity of those civil engineers listed is government service, 28.39 per cent, which with roads, building construction, and steam railroads account for 73.78 per cent. Telegraph and telephone, electrical machinery, and electric power plants account for 66.34 per cent of the electrical engineers; direct mining operations take 58.67 per cent of the mining engineers, with allied industries requiring an additional third of the total. Of the chemicals 47.2 per cent are employed by chemical factories and petroleum refineries, with the others scattered through 37 industries.

But the mechanical engineer is our particular interest. Of those listed 23.2 per cent are in iron and steel production and machinery, 9.74 per cent in the automobile industry, 5.9 per cent in electrical machinery, and the remainder scattered through 85 other industries with less than 5 per cent in any one. A total of 93 industries is listed for all engineers; of these, mechanical engineers are employed by 88.

The broad interest of the mechanical engineer is common knowledge but this survey gives possibly the first opportunity for a statistical analysis of his interests. These widely diversified interests make the problem of engineering-society organization extremely difficult, particularly in regard to programs and professional-division organization. But the burden and responsibility of the educator is even greater, though he can take courage in the fact that graduates in mechanical engineering have apparently been trained with sufficient breadth to adapt themselves to so wide a variety of interests.

The colleges have a far more difficult problem than the engineering societies, as the former have only four, or at the most six, years to train a man who has not yet chosen his specialty; yet we are asked to educate men so that they can meet on an equal intellectual plane the graduates of arts courses, and at the same time, be prepared to become specialists in at least 88 industries, as well as others which will be born after the youth has left the halls of learning.

We educators welcome this survey of industries, but what we need most is a classification of the engineer's functions. Possibly every thinking teacher has made such a functional analysis for his own guidance but his available data are limited. Such an analysis would be of equal value to engineering societies. The first attempt of the colleges to meet this widening field of the mechanical engineer was a tendency toward specialization, with the introduction of options and electives, but the field has widened so rapidly that this plan has fallen of its own complexity.

The approach to this problem at Columbia University was made some twenty years ago by placing the engineering school on a graduate basis, thus putting it in the same status as the other professional schools such as law and medicine. Modifications in the mechanical-engineering course were made from time to time by the condensation of one subject to permit the introduction of another, but no basic change was made until recently. The major difference between the course at Columbia and those of other schools has been that its graduate position has given more available time and enrolled students of greater maturity, capable of more intensive work. The inflexibility of the standard course has been increasingly evident, and as the result of some ten years of planning, the old curriculum has been entirely abandoned and a new one has been in effect during the last academic year. Time alone can tell of its success, but the first year's experience is most encouraging.

Since the training of specialists in 88 departments is impossible, even if desirable, a simpler classification is necessary as well as a functional analysis of the engineer's duties. The latter is too large a subject to discuss adequately in this brief article, but certain personal and mental characteristics are obvious with any analysis. The engineer must not be superficial, he must think straight and he must have the courage of his convictions and be ready to hold them against all odds; he must show initiative and resourcefulness; and in all his thinking he must be sound in his economics and be conscious of the social impacts of his work. These are only in part matters of curriculum; they are chiefly results of teaching methods throughout the entire course. No curriculum can insure this result; no catalog can guarantee it. The result is shown in the average graduate, not in the outstanding one, for many of the latter have succeeded in spite of the teaching.

About ten years ago Dr. C. E. Lucke, head of the department, suggested that all mechanical engineering might be divided into three divisions, manufacturing, power, and transportation. The foundation of all these consists of the sciences, mathematics, physics, chemistry, language, and the fundamentals of good citizenship, the superstructure being economics and management. There is, of course, some overlapping in such a division, but it has proved to be a simple and useful point of view. In a college curriculum it permits some specialization without sacrifice of fundamentals.

With this classification as a foundation for more detailed analysis, the activities and industries of the mechanical engi-

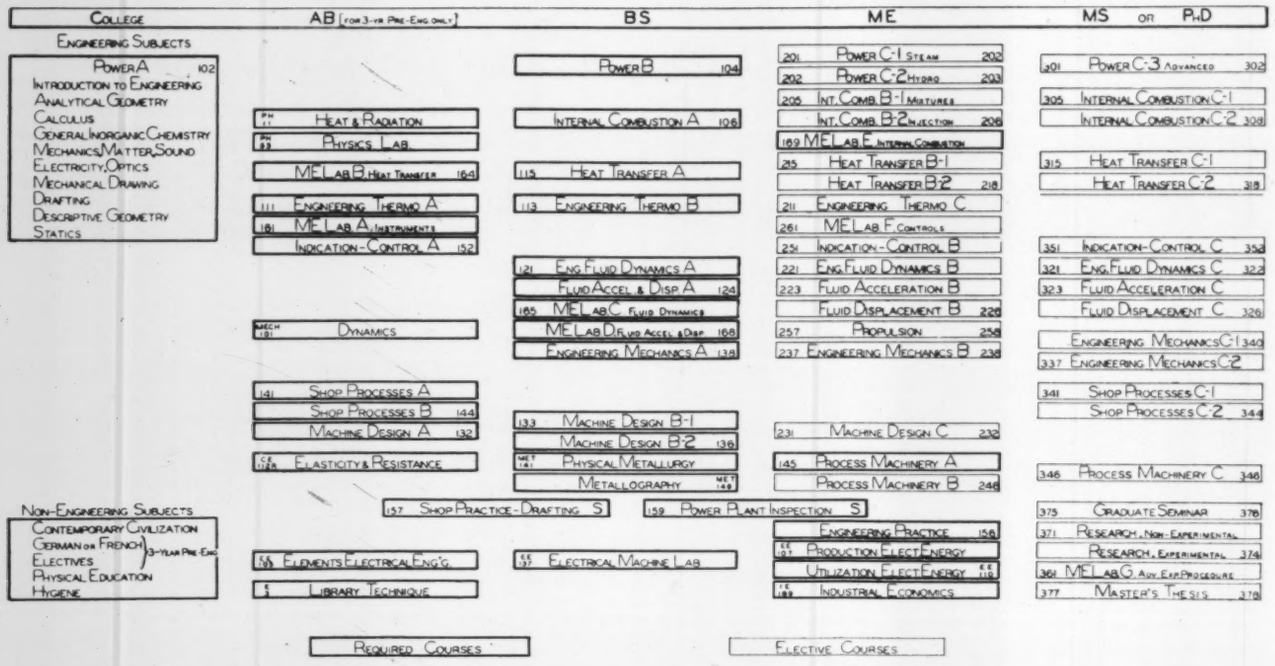


FIG. 1 SCHEDULE OF COURSES OFFERED BY THE DEPARTMENT OF MECHANICAL ENGINEERING, SCHOOL OF ENGINEERING, COLUMBIA UNIVERSITY, NEW YORK, N. Y.

(Course numbers refer to Engineering School Announcement. Numbers in left end of box indicate winter session; those at the right, spring session.)

neer were listed as completely as was practical. Much help was obtained from the subjects covered by the professional divisions and the research committees of the A.S.M.E. and mechanical-engineering handbooks. These were then grouped as to basic science and by functions. This grouping showed conclusively the close inter-relation and interdependence of specialties often considered as far apart as the poles. For example, steam turbines, pumps, propellers, aircraft, and chimneys are, basically, problems in fluid dynamics. Likewise, the design of steam turbines, water wheels, fans, ejectors, and centrifugal separators are problems in fluid acceleration, while steam engines, pneumatic tools, and vacuum pumps offer problems in fluid displacement. Under the old curriculum students who have studied steam turbines are frequently at a loss to determine the reaction of an air jet. Although the technique of these problems differs materially the fundamentals are the same, but the student needs to be shown this similarity. Once having been trained in this method of approach he will begin the problems in later life in the same manner.

The Columbia plan, therefore, includes no courses in specific machinery except as advanced electives. Specific machinery is grouped with allied apparatus, but no sacrifice has been made in teaching the essential technique of each problem.

As the course now stands, two years in any accepted college and two years in the engineering school leads to the B.S. degree and an additional year to the graduate degree of M.E. Three years in the college and one year in the engineering school leads to a degree of A.B., but two years more are required for the degree of M.E. The final or graduate year is largely elective and may be broad or specialized depending upon how the student's interests have crystallized.

One other principle was laid down by Dr. Lucke. Each subject must contain a beginning and an end to the knowledge within that field; at one end an elementary survey or qualitative course, at the other an advanced course which carries the doctorate candidate to the boundaries of knowledge within that subject, and between these two limits a link to bridge the gap between the bachelor and doctor. For convenience these courses are designated undergraduate (A), master (B), and doctor (C). Since we consider the engineering degree a graduate one, all A courses are required and certain B courses for the degree of mechanical engineer. The C courses are optional in the last or graduate year.

The Columbia plan divides the field of mechanical engineering into nine basic, four application, and two general divisions as follows:

THE COLUMBIA PLAN

Pre-engineering (Liberal Arts and Sciences) in College
Engineering School

Basic

(1) Engineering thermodynamics
(2) Engineering fluid dynamics
(3) Engineering mechanics
(4) Fluid acceleration and displacement
(5) Heat transfer
(6) Machine design
(7) Shop processes
(8) Process machinery
(9) Indication and control

Applications

(10) Power; steam, water, gas and oil, stationary, locomotive, and marine
(11) Current engineering practice
(12) Propulsion
(13) Internal-combustion engines[1]
(14) Laboratory
(15) Summer work
(16) Courses by other departments—chemistry, metallurgy, law, economics

[1] This is given a separate heading because it is a combination of machine design, combustion, heat transfer, and power.

Each of these subjects (except 11, 12, 14, 15, 16) is divided into three sections: A, undergraduate (B.S. or A.B.); B, graduate (M.E. or M.S.); and C (M.S. and Ph.D.), although in one or two cases the B course is also included in undergraduate requirements. All C courses are elective and only for students holding a baccalaureate degree.

Limitation of space makes it impossible to define adequately the subject matter of these courses. Many are self-explanatory but one or two need amplification. For example, No. 9, indication and control, comprises the study of engineering instruments and the application of their principles to the control of machines and processes. No. 11, current engineering practice, treats from an engineering viewpoint the application of a variety of engineering principles presented in other courses, to specific problems. It is an introduction to engineering practice stressing the relation of the engineer to his fellow man and includes not only technique but professional ethics. No. 12, propulsion, is a single course devoted to the problems of resistance to motion; the power to accelerate, and the power to hold speed of all kinds of vehicles, from ships to aircraft, and from automobiles to hoists and conveyers. No. 15, summer work, gives the student his first experience as an employee "on his own." The sequence of these courses under the Columbia plan is shown in Fig. 1.

The curriculum committee was originally charged with the responsibility of preparing an ideal curriculum. When that part of the program had been completed the committee was confronted with the continuing task of settling numerous detailed problems of a working curriculum and of correlating and supervising the actual context of courses to see that the departmental ideas were actually carried out. There is only one real way of gaining this end; it requires the use of engineering methods in the writing of detailed specifications for each course. These specifications must show in detail the subject matter for each period of course meeting. As a consequence the courses are laid out in specifications of topics by periods. When the specifications are approved by the curriculum committee and the executive officer jointly and severally, they then serve as the operating basis for the course in question. Supplementary material is then prepared for each course specification to include reference lists of books, professional journals, and manufacturers' trade catalogs. The committee is not concerned with the details of these reference lists as the selection of such material is the province of the instructor in charge of the course, who is, presumably, the authority on that subject.

The preparation of the course specifications is made by the instructor who is responsible for presenting the course. The designation of the individual staff member to such duty is a prerogative of the executive officer. The Columbia staff, as at present constituted, is equipped with at least one specialist in each of the major curriculum divisions. Two staff members have been assigned to each subject classification. One of these gives the A and the C course while the second gives the B course. This results in an advantage to the student as he profits by two points of view in each subject. The two instructors in each subject give assurance of continuity of teaching competence and the arrangement cares for the problems of personnel absence because of illness or of sabbatical leave.

The experience of one academic year with the Columbia plan has been most encouraging to both faculty and student. Of course only time can tell the result of any teaching system, but this plan has been adopted only after a number of years of study by the entire department whose members were educated in seven different schools. The plan seems logical and it is hoped that it will result in a breadth of view without sacrifice of depth of thought.

Harry Leigh Irwin

BATTERY OF MACHINES THAT COAT BARYTA ON PHOTOGRAPHIC PAPER AS A PREPARATORY LAYER FOR THE SENSITIVE PHOTOGRAPHIC EMULSION, KODAK PARK, ROCHESTER, NEW YORK

MECHANICAL PROPERTIES *of* MATTER

By IRVING LANGMUIR

RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

THE remarkable advances in physics in recent years have been such as to arouse wonder and admiration from even the layman. The relativity theory, cosmic rays, and the uncertainty principle have furnished the newspapers with subject matter for many front-page columns.

The pace at which these discoveries proceed seems to be ever accelerating. Just within the last year or so many new fundamental particles have been discovered, such as the neutron, the positron, and now, the neutrino. When we think how much our knowledge of chemistry and physics has been increased by the atomic theory, it would seem that the existence of still other particles must be of corresponding importance in the future development of science. These are, in fact, days of the greatest excitement for the physicist. The enthusiasm which permeates the pioneer in this field stimulates the young graduate student to try his hand at similar discoveries.

The advance of modern physics today resembles in many ways the motion of an ameba. This small animal sends out pseudopodia in various directions. If one of these protuberances happens to extend toward some attractive morsel, the organism, through something analogous to a sense of smell, becomes excited. The other pseudopodia are withdrawn and the whole mass of the ameba flows into the pseudopod which received the encouragement. In the case of the ameba this process is very effective in taking the animal to its food.

The physicists of today behave in a similar way; they all tend to crowd into the extreme outpost, thereby withdrawing from other sectors. Of course, all analogies fall down if pushed too far. It may be objected that the advance in physics differs from that of an ameba in that it leaves a trail behind it. It is true, however, that the physicists do not seem to be aware of the need of adequately developing the side branches from their path of progress. Such work has too often been carried on by engineers without much further help from the physicist.

The quantum theory has led the physicist on to new fields. Obviously, since it gives an understanding of the structure of atoms, it should revolutionize our ideas of chemistry. The physicist, however, is as a rule not interested in the chemical aspects of his work, and very few chemists are familiar with the details of the quantum theory. Thus progress is slow. According to newspaper comment, the distinctions between physics and chemistry are fast breaking down. Actually, this is true only in a narrow field that lies at the borderline between these two sciences. The chemist and the physicist have different habits of thought and different types of interest. How fundamental these distinctions are is illustrated by the fact that of the approximately 2700 chemists listed in "American Men of Science" (1927 Edition) only 2.5 per cent are members of the American Physical Society. On the other hand only 3.3 per cent of the 760 physicists belong to the American Chemical Society. There is obviously not much overlapping of interest. Evidently, therefore, physicists themselves are not going to take the trouble to revolutionize chemistry.

In speaking recently before a group of graduate students of the Massachusetts Institute of Technology I pointed out that the physicists were losing a great opportunity. A large part of the men who are working for doctor's degrees in physics are now undertaking theoretical rather than experimental work, and the problems that they are attacking are not those that enable a man to earn a living unless he continues to work in a university or is able to get some sort of fellowship. The physicists often complain of the fact that the number of physicists in this country is so small that they have great difficulty in supporting the physical journals that they publish. The American Physical Society has only about 3000 members, whereas the American Chemical Society has about 17,000.

There is today, I believe, a great opportunity for men who will train themselves in modern physics and who will then devote their lives to the applications of the new physics to the study of the properties of matter. By this I mean not new and unfamiliar properties, but the old-fashioned properties which were being studied 50 years ago.

In 1880 to 1890 a great deal of work was done in investigating the measurements of the surface tensions of liquids. Lord Rayleigh alone published over a dozen papers on this subject. In 1915 I received a letter from him saying that he discontinued this work about 1892 because nobody seemed to take any further interest in it. My own work on surface tension and surface chemistry resulted merely from the attempt to understand these surface phenomena in terms of the atomic theory, merely applying the accepted ideas of chemical structure and of the nature of the forces exerted by atoms.

I feel that there are many other fields which have been neglected for many years, where similar application of even the atomic theory would lead to a new understanding. The difficulty is that at present the fundamental mechanical properties of matter do not much interest either the physicist or the chemist, and yet the ideas of both chemistry and physics should be the means of developing our knowledge of these properties.

There are some cases, of course, where problems of this kind are being attacked successfully. For example, the mechanical properties of rubber are being correlated with the chemical and physical structure of rubber. In Schenectady we are trying to do the same thing with the various other plastic materials and condensation products.

In the study of the mechanical properties of metals and ceramic materials modern physical and chemical theories should prove to be of the greatest value. For example, if a finely divided material, such as tungsten, reduced from its oxide by hydrogen, is heated to high temperature it gradually sinters together. The phenomenon of sintering is of great importance in metallurgy, and particularly so in the ceramic industries. I believe that no fundamental work on the nature of this process has been undertaken. The attempts at an understanding of lubrication and adhesion have been very superficial.

What I urge is that the mechanism in such processes be studied until it is well understood. This would probably at first not need anything much more than the atomic theory. Later, however, a still better understanding of all such phenomena could be developed by the modern physical concepts of the quantum theory.

I venture to predict that during the next ten or twenty years discoveries of great importance will be made in developing materials having new mechanical properties by the applications of modern physics and chemistry.

From an address delivered at the Semi-Annual Meeting, Cincinnati, Ohio, June 20, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, when the Holley Medal was bestowed upon Dr. Langmuir.

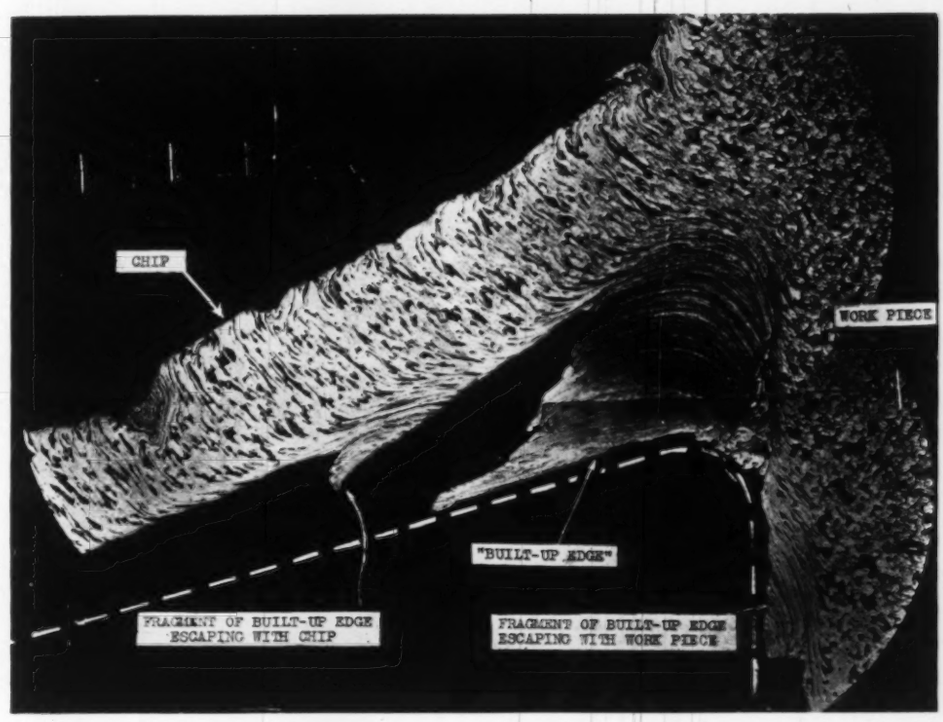

CHIP
WORK PIECE
"BUILT-UP EDGE"
FRAGMENT OF BUILT-UP EDGE ESCAPING WITH CHIP
FRAGMENT OF BUILT-UP EDGE ESCAPING WITH WORK PIECE

FIG. 1 COMPOSITE PHOTOMICROGRAPH SHOWING LATHE CHIP IN THE ACT OF BEING REMOVED FROM THE WORK PIECE
(Radial infeed of tool 0.020 in. per revolution; material, S.A.E. 3115 steel; cutting speed, 83 fpm.)

METAL CUTTING

The Formation and Function of the "Built-Up Edge"

By HANS ERNST and M. MARTELLOTTI

CINCINNATI MILLING MACHINE AND CINCINNATI GRINDERS, INC.

IN ALL studies of chip flow, one of the most outstanding facts observed is that there exists, under certain conditions, a relatively stationary wedge-shaped body of material which precedes the nose of the cutting tool, and appears to cling thereto, while the main body of the chip flows over it. The existence of this phenomenon has long been known, but only in recent years has any considerable attention been given to a study of its occurrence, and to the profound influence which it exerts both on the quality of surface produced on the work and the wear on the cutting tool. The investigations of Rosenhain and Sturney,[1] E. G. Herbert,[2] and others, and the high-speed photomicrographs of F. Schwerd[3] have shown the existence and change of form of the wedge-shaped structure with various materials, depths, and cutting speeds and with various angles of the cutting tool; nevertheless, there is still a great deal of misunderstanding in regard to its formation and the factors which promote or retard its development. Even among those who have studied it closely there are fundamental differences of opinion as to how it is formed. Some have asserted that it is composed of an aggregation of small particles, scraped from the work surface by the extreme edge of the tool, which form themselves into a solid mass wedged between the tool and the chip. Others have stated that it is formed by the welding together of successive layers of metal, each in turn being formed of material dragged back by friction from the flowing chip and consolidated into a hard layer.

Even the name which is generally adopted for this phenomenon, viz., "built-up edge," indicates the absence of a clear understanding of its formation, being indeed a relic of the early conception of an accumulation of particles; while the term "deformed zone," adopted by Rosenhain, neither suggests its true importance nor distinguishes it properly from the chip itself, which is also greatly deformed. Even the term *Schneidenansatz* (literally, cutting appendage) which is adopted by Professor Schwerd and other German investigators does not properly

[1] "Flow and Rupture of Metals During Cutting," by W. Rosenhain and A. C. Sturney, Proceedings, Institution of Mechanical Engineers, January, 1925, p. 141.

[2] "Work-Hardening Properties of Metals," by E. G. Herbert, Trans. A.S.M.E., 1926 p. 705.

[3] "Forschung und Forschungsergebnisse zur Schnitt-Thevine," by F. Schwerd, *Zeit. V.D.I.*, Dec. 24, 1932.

Contributed by the A.S.M.E. Special Research Committee on Cutting of Metals and presented at the Annual Meeting, New York, N. Y., December 3 to 7, 1934.

indicate its formation and function. However, until some more appropriate name is suggested, and in view of the wide use both in England and America of the common term "built-up edge," it will be wiser here to continue to use it.

The practical importance of a study of the formation of the built-up edge arises from the fact that its existence and magnitude greatly influence the quality of surface produced on the work and the mode of wear of the cutting tool. Accordingly, if we can obtain a clear understanding of its formation, we shall be better able to modify the design of the cutting tool, or the conditions of the cut, so as to obtain its advantages, or obviate its disadvantages, as the case may require.

The photomicrograph Fig. 1 is a typical example of a well-defined built-up edge. The machine used in this case was a lathe, and the cut was permitted to continue freely for some time before it was suddenly stopped. Even a casual examination of this illustration will show the two principal distinguishing features of a cut of this type, namely, that in the main body of the chip, the elongation of the crystalline grains (or the flow) is in a direction approximately perpendicular to the face of the tool, while in the built-up edge it is roughly parallel thereto. It is this parallel or *lateral* flow-structure in the built-up edge that has given rise to the various "aggregation theories" of its formation. The term lateral is used here to indicate a flow

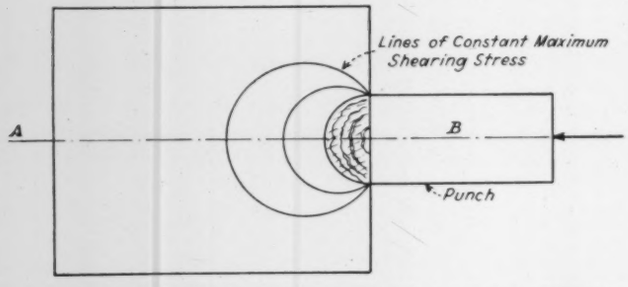


FIG. 2 GENERAL SHAPE OF ISOCHROMATICS (OR LINES OF CONSTANT MAXIMUM SHEARING STRESS) WHEN A BODY IS INDENTED BY A FLAT PUNCH

substantially perpendicular to the principal, or longitudinal, flow.

In their report on the flow and rupture of metals during cutting, Rosenhain and Sturney[4] describe three characteristic types of chip, i.e., (*a*) "tear" type, (*b*) "shear" type, and (*c*) "flow" type. The chip shown in Fig. 1 in the process of removal is obviously of the flow type, as only in this type of chip formation do we find a completely formed built-up edge separated at its upper end from the body of the chip. Nevertheless, contrary to the assumption of some earlier investigators, the lateral flow which characterizes the built-up edge and which causes its development exists also in both the shear and tear types of chip formation; and it is one of the objects of this investigation to show that a progressive lateral flow adjacent to the tool face is a necessary condition in all metal cutting, the difference under different conditions of speed, depth, tool angle, and material being one of degree only and not of character.

In studying the formation of this region of lateral flow adjacent to the tool face we must begin by considering the distribution of stress in a body of material under a simple indentation. As is now well known from published reports of photoelastic tests,[5] the indentation of a body by a flat punch produces a stress distribution in which the lines of constant

[4] Op. cit.

[5] "Plasticity," by A. Nadai. McGraw-Hill Book Co., New York, 1931, p. 248.

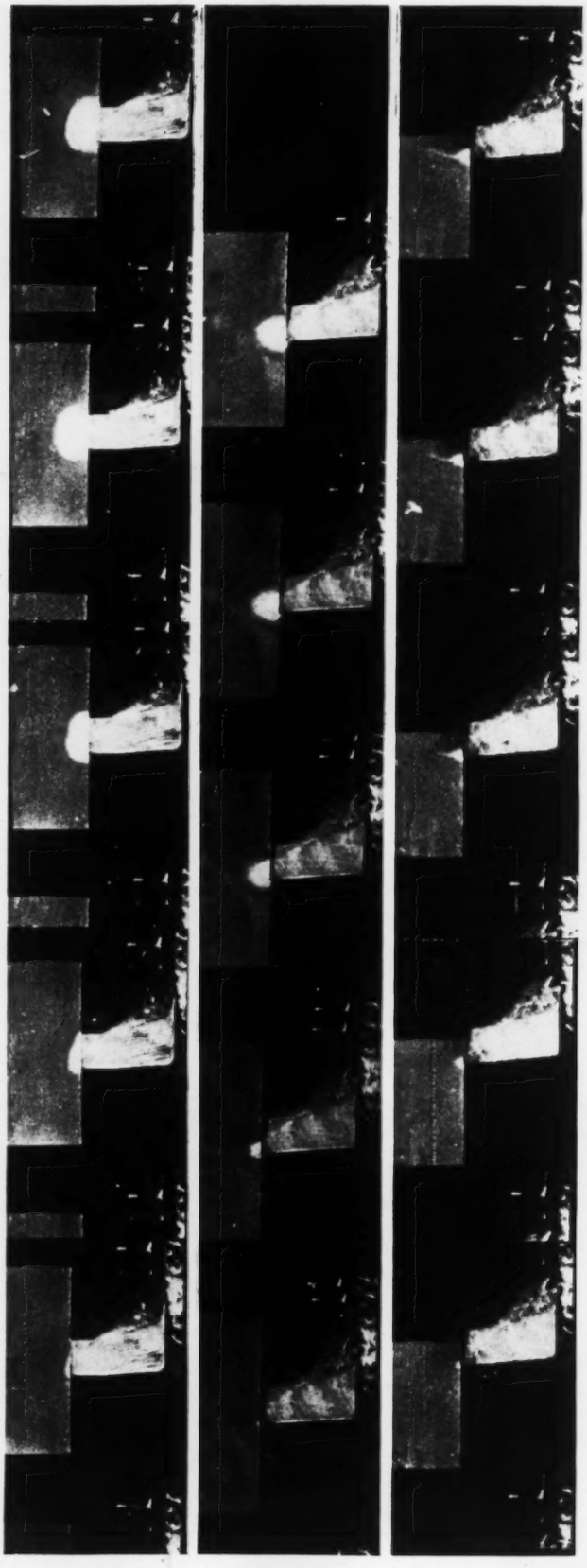


FIG. 3 FIG. 4 FIG. 5

shearing stress are a family of curves approximately circular in form passing almost through the corners of the punch, with a sharp concentration of stress at these corners. Under such conditions there exists (as shown in Fig. 2) a semicircular region adjacent to the face of the punch in which the material may be stressed above the elastic limit, and thus be plastically deformed. If the compressed material in this region be free to escape toward the sides of the block, plastic flow will take place in these directions.

If the face of the punch be now slightly inclined toward the face of the block, the lines of constant shearing stress will no longer be symmetrically arranged with respect to the horizontal line $A - B$, but will be greatly distorted, with a particularly high concentration of stress at the point of contact. In this case the plastically deformed region has a relatively free path for escape in an upward direction. Thus in a crystalline material the grains will be elongated in this direction, and a section normal to the face of the punch will exhibit a flow structure substantially parallel to the face of the punch.

These conditions are shown still more clearly in the series of motion pictures Figs. 3, 4, and 5, demonstrating the identation of paraffin blocks. Paraffin is a particularly suitable material for showing the extent of plastic deformation because of the remarkable increase in opacity of the deformed region.

Fig. 3 is a selected group of pictures taken from a film showing the indentation of a paraffin block by a flat-faced tool, the face of the tool being almost parallel to the face of the block. The block was held securely in a vise clamped to the table of a milling machine, while the tool was carried by a standard arbor support attached to the overarm. Indentation of the block was obtained by feeding the table against the stationary tool, while the pictures were made with a motion-picture camera operating with a film speed of 32 apertures per second.

These pictures clearly show the development of the plastically deformed region ahead of the tool as the indentation proceeds.

In Fig. 4 all the conditions are the same as in Fig. 3 except that a tool with 10-deg front rake angle is used. Here the plastic deformation begins at the nose of the tool immediately following its contact with the block, and spreads rapidly forward and upward. Owing to the fact that only the lower portion of the tool is at first in contact with the block, the deformed material is free to escape upward, thus reducing the rate of increase of pressure on the face of the tool.

In Fig. 5 the same tool is used as in Fig. 4, but the indentation is now made at a point relatively close to the top of the block. The initial development of the plastically deformed region and the upward escape (or lateral flow) are precisely the same as in Fig. 4; but with continued advance of the block, the area in contact with the tool becomes greater, and thus the pressure upon the tool face increases, causing an increasing spread of the plastically deformed region.

As the advance continues, a fracture finally develops near the lower surface of the deformed region and travels the upper surface of the block in a direction approximately perpendicular to the face of the tool.

The example of successive plastic deformation and rupture shown in this series of pictures actually illustrates the basic processes involved in all metal-cutting operations, i.e., first, a progressive lateral flow of the material *parallel* to the tool face, and second, a bodily movement of the chip in a direction *perpendicular* to the tool face. The extent to which each of these processes is involved in any given case, and thus the particular type of chip formation produced, depends on the multitude of factors which affect metal-cutting operations, such as the work material, the tool angle, the depth of cut, and the cutting speed; but in order to determine the relative effect of these factors on the chip-flow mechanism, we must make a more detailed study of the stress distribution in the material being cut and the relation between the external forces on tool and work.

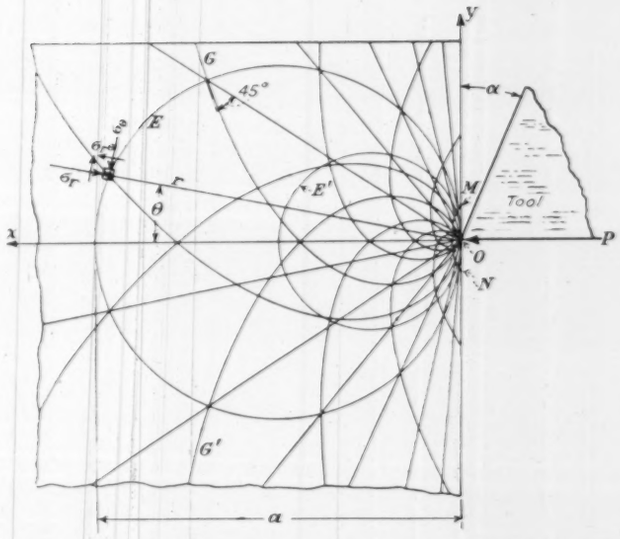


FIG. 6 SCHEMATIC REPRESENTATION OF TOOL AND WORK ILLUSTRATING THE CONDITIONS EXISTING AT THE BEGINNING OF A CUT (Note the shape of the shearing stress trajectories such as G and G'.)

Fig. 6 is a schematic representation of tool and work illustrating the conditions existing at the beginning of a cut. The type of loading is that of a force concentrated at a point on a straight boundary. The stress is distributed radially as a simple compression (or radial normal stress σ_r) from the point of application O, to any given point in the material.[6] In such a case, the tangential normal stress σ_θ, and the shearing stress $\sigma_{r\theta}$ acting on a plane perpendicular to the radius vector, are both zero.

If σ_r represents the radial normal stress at any point on a given circle of diameter a, then its magnitude in terms of the applied force P and the angle θ will be

$$\sigma_r = -\frac{2P}{\pi}\frac{\cos\theta}{r} \qquad [1]$$

where P is the load per unit thickness.

But the radius vector $(r) = a\cos\theta$.

Hence

$$\sigma_r = -\frac{2P}{\pi a} \qquad [2]$$

From this it follows that for any given load the radial stress is the same for all points of any given circle passing through the point O and tangent to the y-axis, except for the point of application of the load, where the value of σ_r theoretically approaches infinity.

From an inspection of Equation [2] it is obvious that the relation between the diameter a and the stress σ_r may be represented by an equilateral hyperbola, thus showing that the radial stress decreases hyperbolically from infinity at the point of application (where the diameter of the stress circle a is zero) to zero where the diameter of the stress circle is infinity.

As the maximum shearing stress at any point is equal to one-half the difference between the radial normal and the tangential

[6] J. H. Michell, Proc., London Math. Soc., vol. 32, 1900, p. 35.

normal stresses, or $(\sigma_r - \sigma_\theta)/2$ and as σ_θ in this case is zero, the maximum shearing stress is equal to $\sigma_r/2$.

From the foregoing it is evident that the distribution of radial stress in the material may be represented by a family of circles, such as E and E', passing through the point of application of the load, hence it follows that the points of constant maximum shear will likewise lie on a similar family of circles. These are identical with the well-known dark fringes, or isochromatics, which are obtained in photoelastic tests under similar conditions of loading.

Traversing the isochromatics are two additional systems of curves which are of particular importance in the study of metal cutting. These are the shearing stress trajectories, which consist of two orthogonal systems, such as G and G', having their origin in the point of application of the load, and which, in the case under consideration (Fig. 6), intersect the lines of radial normal stress at 45 deg. At any point in the material, the tangent to a shearing stress trajectory is the direction along

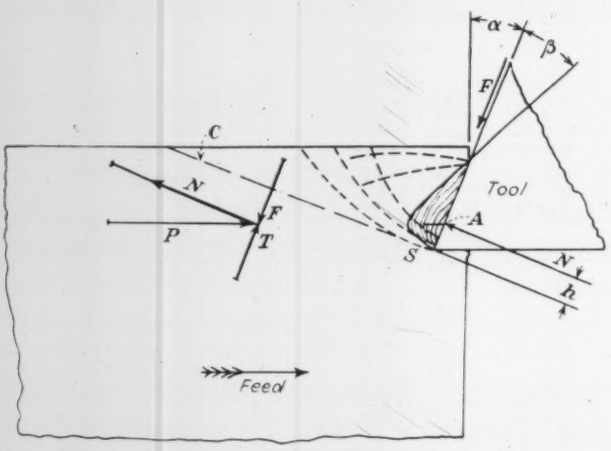


FIG. 7 CHANGE IN STRESS DISTRIBUTION AS TOOL ENTERS FURTHER INTO THE WORK

(Center of pressure on tool rises to the point A.)

which the maximum shearing stress acts, thus it is along these lines that the material will yield, or flow, when the value of the shearing stress exceeds the elastic limit. This fact is demonstrated by the familiar slip lines, or Lüders' lines, which appear on the surface of a steel bar under a tensile test at the instant that the yield point is reached. Regular systems of slip lines are also observed in compression and indentation tests, and in such cases there is a remarkable correspondence between the mathematically determined network of shearing stress trajectories and the observed positions of the slip lines for equal condition of loading.[7]

In the case shown in Fig. 6, the stress gradient along the trajectory is by no means the same for all trajectories. The slope of this gradient, or rate of change of maximum shearing stress, depends on the magnitude of the stress at the origin and the distance which it traverses to the point of zero stress, where it emerges from the free boundary of the work piece.

From Fig. 6 it is clear that the shortest trajectories, and thus the ones possessing the steepest gradients, are those which emerge from the work piece at points adjacent to the nose of the tool, as at M and N; thus, as the tool first enters the work surface, the flow of the material will be in these directions.

Owing to the particular shape of the tool, its advance into the work brings about a change in the force distribution. As the contact with the work piece is on the inclined front face only, the trajectory network is no longer symmetrically disposed with respect to a horizontal line passing through the point of contact, but is distorted and inclined upward. The shearing stress trajectories with maximum stress gradient are now obviously those extending upward and close to the face of the tool. Thus, as the advancing tool causes additional layers of material to be stressed beyond the elastic limit, this material will flow along these trajectories toward the free space further along the face of the tool, thus producing the region of lateral flow which is characteristic of the built-up edge.

As shown in Figs. 4 and 5, the continued advance of the tool causes an increasing spread of the plastically deformed region, and a continued flow of this material in a direction generally parallel to the tool face, thus increasing the area of contact between tool and work.

As the contact area is increased, a new condition arises which causes a further change in the stress distribution. This is the increasing value of the friction force which opposes the upward flow of the material along the face of the tool and a shift in the position of the center of pressure which so modifies the external force system as to produce a considerable change in the values of the principal stresses. The increase in the friction force acts to reduce the gradient of shearing stress in the trajectories along which the upward flow took place, while the change in the external force system introduces an increasing tensile stress in the material immediately ahead of the point of the tool. The existence of the tensile stress in this region has been shown also by Professor Coker[8] in a photoelastic study of the stress distribution in tool and work under various cutting conditions.

When the point of the tool first entered the work surface, the contact area was extremely small and thus the center of pressure on the tool was very close to the point. As the contact area increased, the center of pressure moved further and further away from the point and up the face of the tool.

Fig. 7 is a diagrammatic representation of this condition, showing the relationship between the external forces involved. The center of pressure is here indicated by the point A, which we may assume as the point on which the entire force P between tool and work will act. The component of the force P acting along the plane is designated as T, and the reaction normal to the plane is designated as N. The friction force F acts in the plane of the tool face in opposition to T.

If the front rake angle on the tool is α, then $N = P/\cos \alpha$ and $T = P \sin \alpha$

$$F = fN$$

where f = coefficient of friction between the plastically deformed region and the tool face.

Thus $F' = F - T$

$$= fP/\cos \alpha - P \sin \alpha = P\,[(f/\cos \alpha) - \sin \alpha]$$

which may be either positive or negative depending on the values of f and α. But N is acting at the point A, which is at a distance h from the point of the tool. Thus we have a moment Nh which tends to impose a tensile stress in the region adjacent to the tool point.

As the increase in the friction force F reduces the stress gradient in the trajectories along which the initial flow took place, flow will occur along trajectories somewhat more remote from the tool face, but with increasing difficulty. As the deformed region increases in extent, and the external force P therefore increases, the stress gradient in the trajectory S encompassing

[7] A. Nadai, op. cit., p. 251.

[8] "The Action of Cutting Tools," by E. G. Coker, Proceedings, Institution of Mechanical Engineers, March, 1925, p. 357.

the lower limit of this region will increase. But in the neighborhood of S, adjacent to the tool point, there is also an increasing tensile stress, due both to the shift in the center of pressure and also to an increase in the angle β between the flow lines which mark the upper limit of the plastically deformed region and the tool face. This is comparable to an increase in the tool rake angle α.

With increasing advance of the tool, a condition is finally reached where the summation of the effects of the shearing stress in the trajectory S and the tensile stress in that region causes a fracture of the material immediately ahead of the point of the tool. This fracture is initially propagated from the point of the tool along the trajectory S, but as it travels forward and upward, the bending moment produced by the force N increases, thus causing a further extension of the fracture through failure of the material under tensile stress.

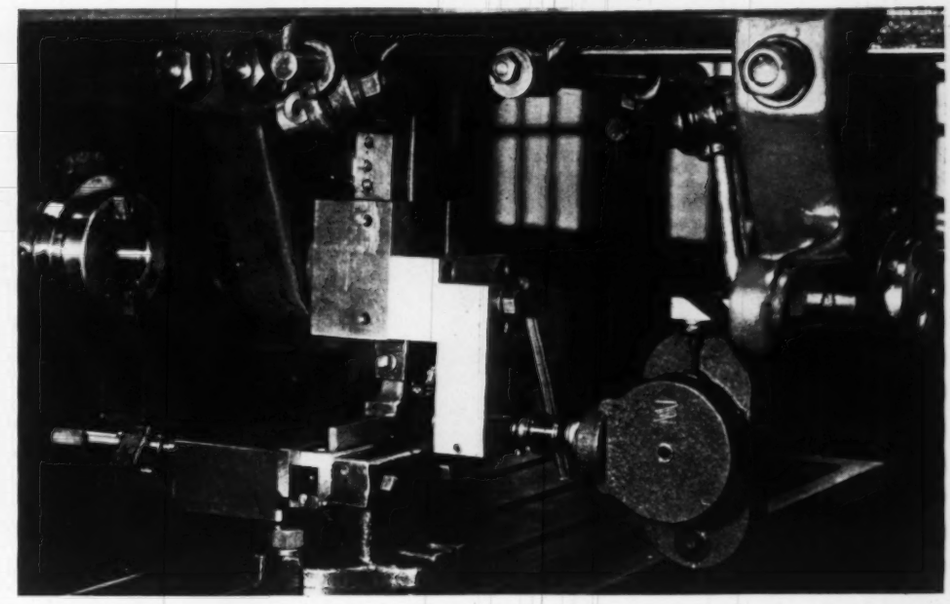


FIG. 8 SET-UP OF MICROSCOPE AND MOTION-PICTURE CAMERA ON MILLING MACHINE WHEN TAKING PICTURES OF CHIP FORMATION

The bending moment likewise produces a compressive stress in the material in the region C. The extension of the fracture along the trajectory S permits a bodily upward displacement or rotation of the material comprising the body of the chip, hence all further extension of the region of lateral flow at the tool point ceases, and this portion, with the rest of the chip, travels bodily up the face of the tool.

The upward movement of the chip body produces a gradual increase in the compressive stress in the region C, which so modifies the stress distribution in this field as to cause a counterclockwise rotation of the trajectory network. This rotation continues until the tangent to the trajectory S at the end of the fracture is approximately perpendicular to the face of the tool. Further movement of the tool produces a complete rupture by shearing along this plane.

As the tool continues to advance, the point engages the material below the surface of the preceding fracture, and thus we have a repetition of the previously described processes, i.e., a plastic deformation with lateral flow up the face of the tool until the contact area and total pressure on the tool have increased sufficiently to produce a relatively large bending moment. This results in a fracture along the shearing stress trajectory bounding the lower surface of the plastically deformed region, and ultimately causes a shear on a plane approximately perpendicular to the face of the tool. With each rupture the entire region of lateral flow passes off with the remainder of the chip segment, as the bond between them has not been severed. Hence the removal of each segment must begin with the development of a new region of lateral flow.

The foregoing description of chip-flow mechanism applies in detail only to the type of chip designated by Rosenhain as "shear type," which is characterized by the fact that the chip is divided into segments more or less completely detached from each other, the separation between successive segments being produced by the rupture just described. This segmental type of chip is familiar to all who have observed metal-cutting operations. It occurs particularly with materials of relatively low tensile strength and with deep cuts. That this should be so is evident from the foregoing analysis, as the initiation of the fracture at the origin of the trajectory S (for a given extension of the deformed region) is due to the tensile stress produced at this point. Where the material of the work piece is of low tensile strength, this stress may be sufficient to cause rupture, while with a material of higher tensile strength it may not. In the latter case the processes subsequently involved are entirely different and will be discussed later.

In order to study the development of the region of lateral flow and the resulting shear normal to the tool face, a number of tests were made with different materials, rake angles, and depths, using a stationary tool attached to the arbor support of a milling machine, while the work piece was carried in a vise attached to the table. A microscope, mounted securely in a bracket, was arranged in line with the point of the tool, while a motion-picture camera was similarly mounted in line with the microscope. The entire set-up is shown in Fig. 8, while Figs. 9 to 11, inclusive, show selected series of pictures from three different tests.

In Fig. 9, the material used is a high-lead bronze, while the tool has a front rake angle of 10 deg. The speed of the cut is one inch per minute, while the depth is $^1/_{16}$ in. In this group of pictures, the successive development of the lateral flow region and the subsequent perpendicular shear are clearly seen.

A conspicuous feature of this investigation was the uniformity in the size of the individual segments for each particular test. In the test shown in Fig. 9, an average of 10.5 segments was produced per inch of table travel.

In the series shown in Fig. 10 the depth of cut was increased from $^1/_{16}$ in. to $^7/_{64}$ in., while all other conditions remained the same. In this case an average of only seven segments was produced per inch of table travel.

In a subsequent test, the depth of the cut was again reduced to $^1/_{16}$ in., but the speed of table movement was increased to 30 in. per min. All other conditions remained the same. In this case nine segments were produced per inch of table travel.

In the series shown in Fig. 11 the tool was changed to one with a front rake angle of 35 deg. The speed was one inch per minute, the depth $^1/_{16}$ in., and the work material was the same as in the previous tests. In this case an average of 14 segments was produced per inch of table travel.

These tests corroborate the conclusions reached from the foregoing analysis. For the same tool angle, the pitch of the segments was less for the $^1/_{16}$-in. depth of cut than for the $^7/_{64}$-in. depth of cut. This is due to the fact that in the case of a shallow cut the region of lateral flow does not reach so large a value before rupture occurs by combined tension and shear. By comparison of Figs. 9 and 10 the difference in size of the region of lateral flow may be readily seen.

In the series shown in Fig. 11, where a tool with a rake angle of 35 deg was used, the pitch of the segments was still less, owing to the greater inclination of the shearing-stress trajectory bounding the lower surface of the deformed region. On account of its greater inclination, the length of the trajectory was shorter and thus the force required to produce rupture was still less than in the case shown in Fig. 9.

For the same depth of cut, an increase in speed caused an increase in the pitch of the segments. This was due to the fact that an increase in the rate of loading produces a change in the stress distribution in the material. This will be discussed at greater length later on.

In additional tests, a reduction in the pitch of the segments was also found with increasing tool sharpness, and with the application of lubricant to the tool face. In the case of increased tool sharpness this is believed to be due to a higher concentration of the stress at the point of the sharper tool, and to the fact that the region of lateral flow does not extend as far under the slightly rounded nose of the tool, as in the case of a tool of lesser sharpness. With a lower resistance to movement of this region along the face of the tool, and a greater concentration of stress at the tool point, the development of a fracture will take place with a smaller advance of the tool. The application of lubricant to the tool face likewise reduces the resistance to sliding along the face, thus reducing the pitch of the chip segments.

Where the material used is of higher tensile strength, the segmental type of chip shown in Figs. 9 to 11 and described in the foregoing analysis may not be produced. As the tool point penetrates the work, the region of lateral flow will develop, as before, by plastic flow along the shearing stress trajectories leading to the free space along the upper portion of the tool face, but the tensile stress produced near the tool point may not be sufficient to cause rupture. In such a case, the tool will continue to advance, thus causing an increasing spread of the plastically deformed region and also an increasing stress gradient along the trajectories in the neighborhood of its lower surface. With a further advance of the tool, these stress gradients will rise sufficiently high to produce a small slip or plastic flow along the trajectories in this region.

This slip along the shearing stress trajectories must not be confused with the rupture previously described. Under certain conditions it may develop into a rupture, but it is not essentially such. In crystalline ductile materials, plastic flow takes place by simultaneous sliding on a multitude of crystallographic slip planes, a relatively enormous aggregate movement being possible without serious destruction of the atomic bonds. In most materials, however, continued motion on a given plane causes an increase in the counteracting forces in this plane and this is the phenomenon which is generally known as work-hardening. If motion be continued still further, rupture will eventually take place.

Opposition to flow in a given plane (by work-hardening) causes a transfer of stress to adjacent planes, thus in the case under consideration a slip along one trajectory causes an increase in the stress gradient along neighboring trajectories. This is further assisted by the continued advance of the tool, and as each successive plane yields in turn, the material above it is forced gradually upward and out of the path of the advancing tool.

This upward movement of the chip body, however, is not without effect upon the outermost layers of the region of lateral flow or built-up edge, as we may now call it. In moving upward and backward toward the tool face the chip body must move relative to the upper surface of the built-up edge, which is itself restrained from motion in this direction. In so moving, therefore, the material eventually fails by shearing along this surface and the two part company. The chip body travels on over the face of the tool, while the built-up edge remains relatively stationary therewith.

Although the upper portion of the built-up edge eventually separates from the body of the chip, this is not true of the extreme forward portion or nose. Obviously, there can be no sharp dividing line at this point between the material which flows along a trajectory leading to the free surface on top of the work and that which flows back toward the free space along the tool face. Thus with each increment of forward movement of the tool there is a small addition of material to the foremost portion of the built-up edge, not a separate layer scraped or dragged off from somewhere, but simply an enlargement by elongation of the previously undistorted crystalline grains of material, in a direction generally parallel to the tool face, instead of perpendicular thereto, as in the case of the grains further ahead.

This conception of a continued enlargement of the built-up edge by material already continuous therewith is in agreement with the results reported by Rosenhain,[1] showing that no discontinuity of surface could be observed between the nose of the built-up edge and the adjacent chip material after heating above the recrystallization temperature.

As the chip flow continues by perpetuation of the tool movement, the built-up edge thus becomes larger and larger, but in so doing it also becomes more and more unstable. The frictional force which opposes the movement of the built-up edge along the face of the tool is acting on the base of the built-up edge, while the shearing force between the flowing chip body and the built-up edge is acting upon its upper surface. Thus with increasing size of the built-up edge, a time eventually comes when the resistance to shear between chip and upper surface of built-up edge is greater than the resistance to shear through some section of the built-up edge itself, and thus a portion of the latter is torn off and travels away with the chip.

In like manner, the continued forward movement of the tool with its built-up edge eventually causes a failure by shear between the lower surface of the built-up edge and the so-called finished surface of the work. With continued enlargement of the built-up edge the resistance to shear on this plane likewise increases, so that at length it becomes greater than the resistance to shear through some section of the built-up edge, and thus a portion of the latter is torn off and travels away with the work.

This building up and intermittent tearing off by both the chip and the work has been noted by Professor Schwerd,[3] and shown in certain of his high-speed photomicrographs. It is also clearly shown in Fig. 1, fragments of the built-up edge carried away both by chip and work surface being within the field of the picture.

From this it appears that we must visualize the fully developed built-up edge as an unstable creation, perched precari-

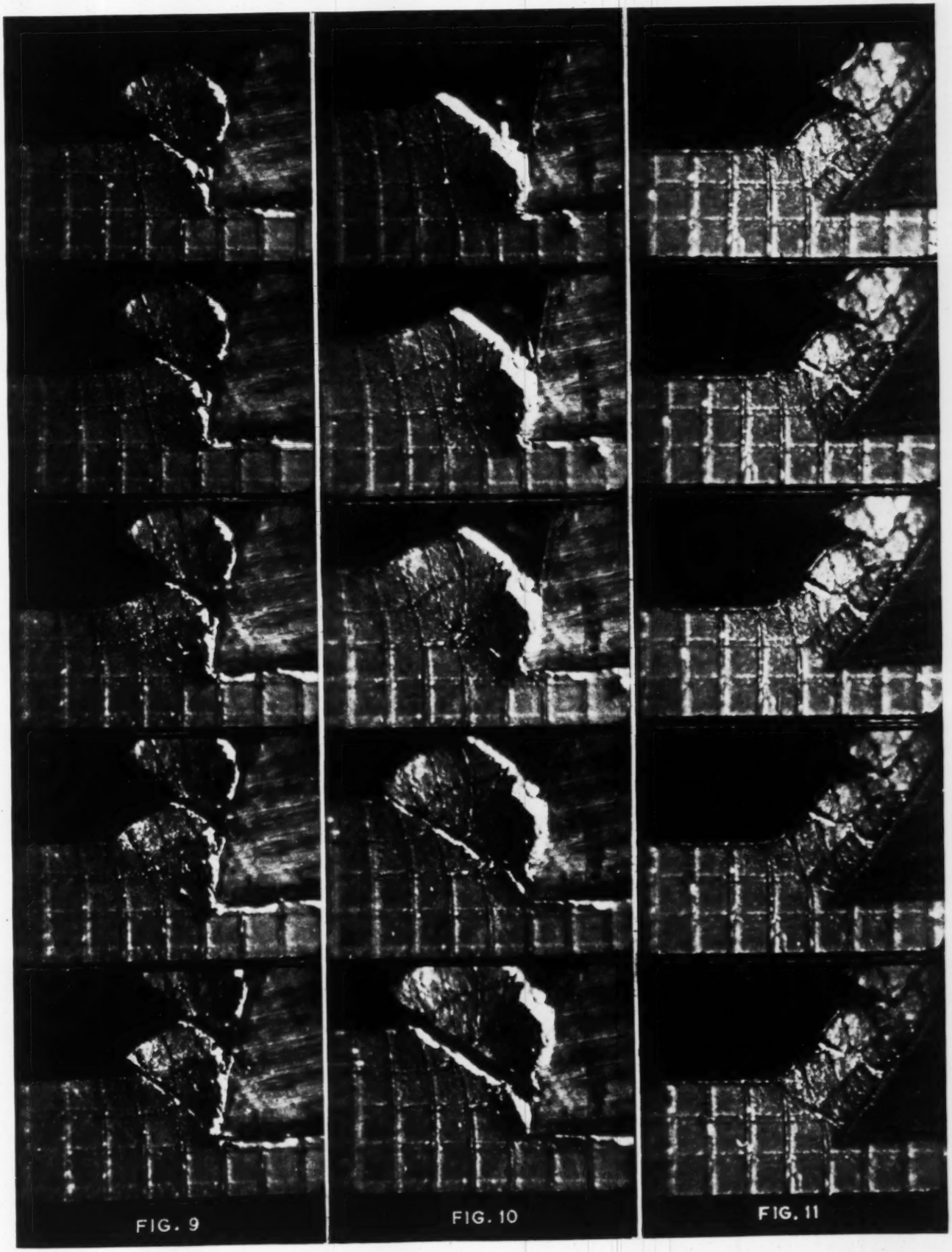


FIG. 9

FIG. 10

FIG. 11

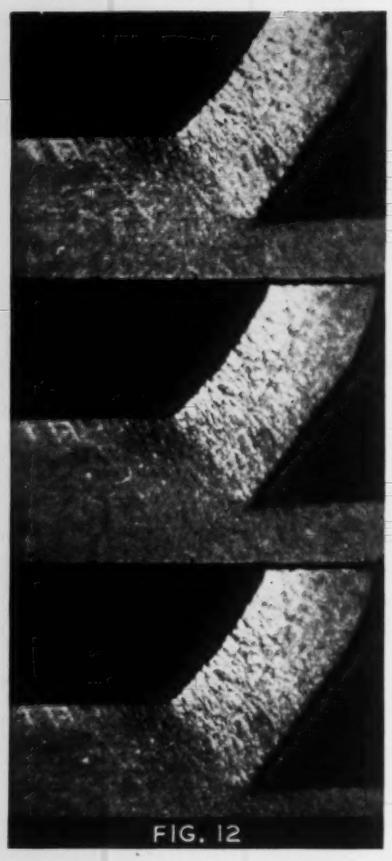


FIG. 12

ously on the point of the tool, and bursting its way through the work piece, integral, in part, with both chip and work, and continually built up therefrom, yet ruthlessly torn asunder and carried off by both. And this is the seemingly, smooth flowing, uniform, flow-type chip formation.

Fig. 12 shows the conditions obtaining with a tool having a front rake angle of 35 deg when cutting a material of higher tensile strength, i.e., rolled sheet brass. The depth of the cut was $^1/_{16}$ in. and the speed was 1 in. per min. In this case it will be noted that there is a complete absence of the segmental chip formation shown in the previous tests. Here we have a true flow-type chip. With the relatively large front rake angle used in this case, the extent of the built-up edge is relatively small, owing to the ease with which the material fails by plastic flow in a direction normal to the tool face. In additional tests it has been shown that with a smaller rake angle, such as 10 deg, the extent of the built-up edge is considerably greater, as would be expected from the foregoing analysis.

The existence and extent of the built-up edge in turning operations has been studied in the past,[1] with various depths of cut and front rake angle, by suddenly stopping the lathe and removing a section of the chip and neighboring work material for microscopic examination. One of the limitations of this method has been that the built-up edge was already fully formed, and thus no information could be obtained as to the processes involved in its formation.

In order to study in detail the development of the built-up edge from the instant that the cutting tool first penetrates the work to the time that the chip is completely formed, we have modified this method to the extent of using a milling machine and spiral milling cutter instead of a lathe. A laminated work piece, with the laminations parallel to the plane of rotation of the cutter, was used for this investigation. As shown in Fig. 13 the use of the laminated block and spiral milling cutter makes it possible to study the structure of the chip and built-up edge at any stage of development.

A special fixture was bolted to the milling-machine table, and arranged with means for clamping the laminations securely together, so as to form, in effect, a solid work piece. The table was fed toward the cutter in the customary manner, and a cut of the required depth was continued until the center of the cutter was well over the end of the work piece. The cutter and feed were then abruptly stopped, and the fixture with laminated work piece was carefully removed so as not to injure the partially formed chip.

The laminations were then removed from the fixture, carefully separated, and heavily plated with copper so as to protect the protruding chip portions and to preserve even the smallest fragment of chip and built-up edge. A small triangular section including the partially formed chip was then cut from each lamination, and mounted in a steel cup containing a low-melting-point lead alloy. The cups and chips were then surface ground to such a thickness as to expose the desired chip section. They were then polished in the usual manner and etched for microscopic examination.

Selected sections from beginning to end of the chip for two different cutting conditions are shown in this paper. In each case the cutting speed was 60 fpm, the depth of cut $^1/_4$ in.; and the feed rate, $9^3/_4$ in. per min. A 4-in. diameter, 10-tooth, spiral milling cutter was used, thus giving a feed per tooth of approximately 0.017 in.

In the one test, as shown in Figs. 14 to 17, inclusive, a sulphurized mineral oil was used as cutting fluid, and the lip surfaces of the cutting teeth were carefully polished so as to reduce as much as possible the frictional resistance to chip flow. In the other test, as shown in Figs. 18 to 23, inclusive, the lip surfaces of the cutter were ground in the usual way, but not polished, and the cutting was done dry. In each case the front rake angle was 10 deg and the clearance angle 5 deg. The material used was S.A.E. 1112 cold-rolled steel.

Much information can be obtained by a careful study of these photomicrographs. Even a casual observation shows

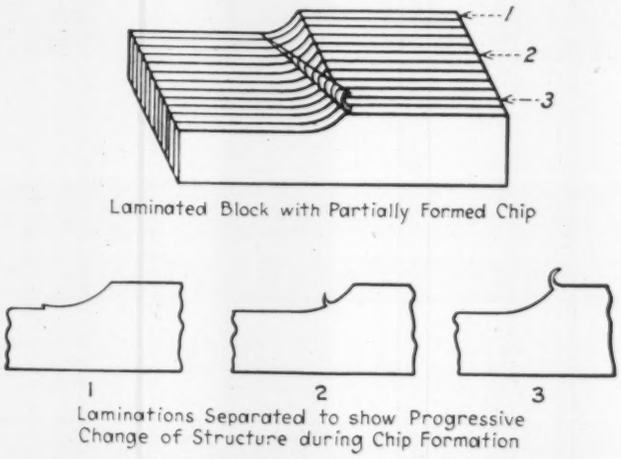


FIG. 13 LAMINATED TEST BLOCK USED WITH SPIRAL MILLING CUTTER TO STUDY THE STRUCTURE OF THE CHIP AND BUILT-UP EDGE AT ANY STAGE OF DEVELOPMENT

that the magnitude of the built-up edge is much greater in the second group of pictures, i.e., when the cutting was done dry (and thus the resistance to chip flow relatively greater). In view of the foregoing analysis concerning the development of the built-up edge, this is precisely what would be expected. Closer observation shows that a certain lateral flow adjacent to the tool face exists in the very early stages of chip formation, but that, where the chip is very thin, as at the beginning of the cut, the extent of this region is relatively small. However, even where the instantaneous depth of cut is only 0.0025 in., as in the case of the chip shown in Fig. 20, a well-developed built-up edge is already produced. At this time the cutting edge has advanced a total distance of approximately $^1/_4$ in. from the point of first contact, and this distance was tra-

Fig. 14

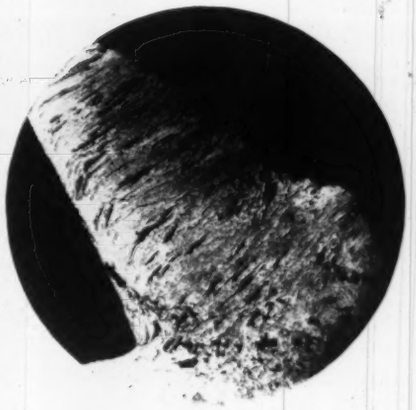


Fig. 15

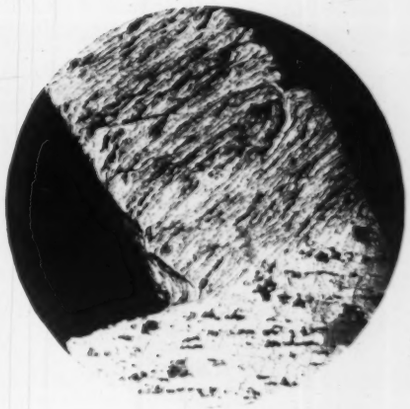


Fig. 16

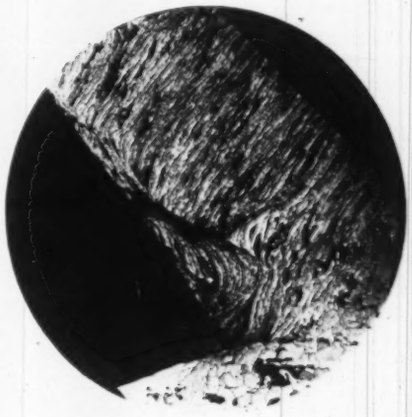


Fig. 17

FIGS. 14, 15, 16, 17 PHOTOMICROGRAPHS SHOWING SUCCESSIVE STAGES IN THE FORMATION OF A MILLING CHIP

(Cutting fluid sulphurized mineral oil.)

versed in a time interval of only $^1/_{40}$ of a second, hence the old notion that the built-up edge requires considerable time for its formation is obviously wrong. Similarly, this also disproves the old theory that the built-up edge is formed by the gradual accumulation of particles scraped from the work surface by the extreme edge of the cutter.

It is interesting to note that as the chip becomes heavier an occasional rupture exists, extending partially through the body of the chip, and that whenever this takes place a considerable portion of the built-up edge passes off with the chip. This is clearly shown in Fig. 17 where it will be noted that there is a definite change in the orientation of the flow in the body of the chip immediately following the partial rupture.

Up to the present time, very little definite information has been obtained in regard to the influence of speed in the formation of the chip, in any metal-cutting operation. Professor Schwerd[3] has shown by means of his high-speed photomicrographs that the mechanism of chip formation is definitely modified by the cutting speed. Further evidence that speed affects the chip formation is given by the motion pictures of segmental chips in which the number of segments per inch of table travel was changed from 10.5 in the case of a cutting speed of 1 in. per min to 9 in the case of a cutting speed of 30 in. per min. In view of the foregoing analysis, this difference appears to result from the fact that the stress distribution in the material for the high cutting speed is not identical with that obtained at the low cutting speed.

That the speed of loading *does* exert a certain influence on the extent of plastic deformation, even in crystalline materials, is generally recognized; but in most cases the effect is so small that it is not of practical importance. In the case of metal cutting, however, where speed is a vital factor in determining both the tool life, and the productivity of the machine, it is important that its influence on the basic mechanism of chip flow be clearly understood.

Some facts are already known. Indentation tests on the edges of relatively thin flat bars of plastic materials show a more highly localized deformation when the load is applied at a high velocity (by a falling weight) than when applied at a low velocity (by means of a screw). In these tests the bars were held in a fixture, and indented by means of a wedge-shaped punch. A positive stop was provided for the punch so that each indentation was made to precisely the same depth. With the high velocity, the width of the bulged portion is greater, but the extent of the bulge over the surface of the specimen is less.

In a series of drop tests on small, carefully prepared and annealed lead cylinders, a definite, small, speed effect has also been observed. These tests were made under two different conditions; a 2-in. drop with a weight of 15.6 lb, and a 20-in. drop with a weight of 1.56 lb. In each case, therefore, the energy transferred from the falling weight to the lead cylinder was the same, but the velocity in the second case was 3.16 times that of the first. In these tests a consistent, small, increase in the extent of deformation was noted for the low-speed test; the cylinders in this case being uniformly shorter than in the case of the higher velocity of impact.

Much additional work is necessary to correlate the results of these and other investigations with the facts observed in cutting tests.

In the results of his investigation of chip formation with turning tools, Professor Schwerd[9] has indicated that at speeds higher than 70 m per min (250 fpm) no built-up edge occurs. This is not fully in accord with the results of our investigations with milling cutters. In our case it appears that it is only the *extent* of the region of lateral flow (or built-up edge) which is changed by the cutting speed; *some* lateral flow adjacent to the tool face exists even at the highest speed tested.

A characteristic of the milling chip is that the residue of the built-up edge remains attached to the end of the chip as it passes from the work. Thus its existence at any speed may readily be determined by merely observing the chips.

In Figs. 24 to 26, inclusive, are shown photographs of milling chips obtained at speeds of 156, 365, and 765 fpm, respectively. Clearly the built-up edge is larger with the lower speeds, but even at 765 fpm there exists a small but well-defined region of lateral flow at the end of the chip adjacent to the surface which was in contact with the tool. In additional tests, a definite built-up edge has been observed even at a speed of 1560 fpm.

[9] Op. cit. See diagram, Fig. 43.

Fig. 18

Fig. 19

Fig. 20

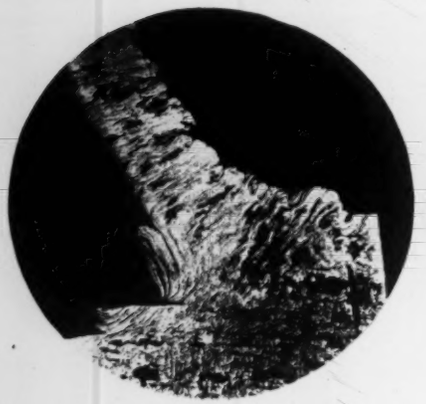


Fig. 21

Fig. 22

Fig. 23

FIGS. 18, 19, 20, 21, 22, AND 23 PHOTOMICROGRAPHS SHOWING SUCCESSIVE STAGES IN THE FORMATION OF A MILLING CHIP
(No cutting fluid used. Note the large increase in the magnitude of the built-up edge.)

Fig. 24

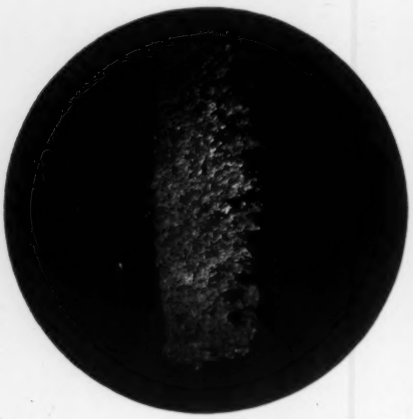


Fig. 25

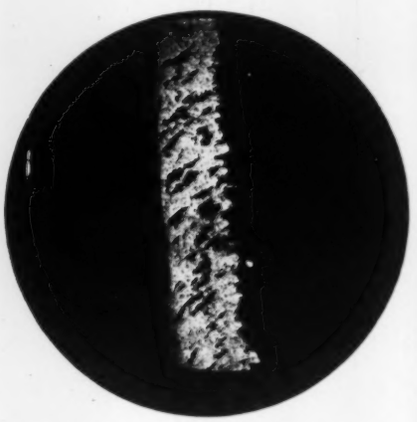


Fig. 26

FIGS. 24, 25, AND 26. PHOTOMICROGRAPHS OF MILLING CHIP FROM SPIRAL MILLING CUTTER
(Fig. 24 Cutting speed 156 fpm, 1/4 in. depth of cut, 0.017 in. advance per tooth, soluble-oil cutting fluid. Fig. 25 cutting speed 365 fpm, advance per tooth 0.014 in. Fig. 26 cutting speed 765 fpm, advance per tooth 0.008 in.)

A possible reason for the apparent absence of the built-up edge at high speeds in other investigations is that the tendency for the machine to chatter is usually greater at high cutting speeds. Chatter is a condition of resonant vibration in which the tool and work piece move with respect to each other at a frequency which is usually determined by the natural frequency of some portion of the work-supporting, or tool-supporting, structure. When this condition has once been established, the interaction of tool and work provide the necessary periodic force system to maintain the oscillation at this frequency.

When chatter occurs, the chip formation is radically different from that existing when chatter is absent. If the conditions

are such as to produce a solid flow-type chip when no chatter is present (Fig. 27*a*), the change to a chattering condition (as by clamping the work piece less securely) will instantly change the chips to the type shown in Fig. 27*b*. In Fig. 28, the structure of the chattered chip is shown in greater detail, and there it will be noted that the flow lines in the chip segments are no longer parallel, as in Fig. 27*a*, but definitely fan shaped. Thus, the chip formation has changed to a type closely resembling the segmental, or "shear" type, previously described. In this case, the region of lateral flow is shown by the flow lines parallel to the face of the tool, but as this region passed off with each segment, no separate built-up edge was developed.

Fig. 29 shows the structure of a chip made under conditions where very light chatter existed. Here the periodic force fluctuation occasioned by the relative vibration of tool and work were insufficient to produce a true segmental formation, as in Fig. 28, yet were sufficient to cause a marked periodic change in chip thickness.

In Figs. 1, 20, 21, and 22 are shown small portions of the built-up edge which have been sheared off by its motion relative to the newly formed surface. These remain permanently attached thereto, and, where this is the finished surface (as in the case of turning, planing, or shaping operations), they produce a rough or torn appearance of the work. Obviously, the larger and more unstable the built-up edge, the larger will be the individual portions carried off by the work, and thus the rougher and more torn will be the appearance of the work piece. Hence it follows, that, to obtain the highest quality of work surface, the conditions should be such as to reduce the magnitude of the built-up edge to a minimum, and to promote its intermittent escape with the flowing chip rather than by attachment to the work surface.

The small size of the built-up edge when the chip is very thin also accounts for the high quality of finish (apart from the revolution marks) which may be obtained with a spiral milling cutter when cutting against the direction of the feed. In this case an element of the finished surface is formed by the highest tooth of the cutter during the first part of its movement through the work. As shown in Fig. 18, the initial portion of the chip is extremely small; in this case being only from 0.0002 to 0.0005 in. thick and 0.010 in. long. The finished work surface is entirely free from rough steps and torn places, such as shown in Fig. 1. The magnification in both cases is the same.

In the matter of tool wear, the built-up edge may be either useful or detrimental, according to the conditions. In the case of a heavy roughing cut on a lathe, the built-up edge is probably very helpful in protecting the upper surface of the extreme edge of the tool, and in distributing the chip load over a relatively large area of the tool surface. On the other hand, the existence of a large built-up edge involves the frequent escape of portions thereof by passage underneath the nose of the tool, as they pass off with the work surface. The escape of these highly work-hardened portions underneath the cutting edge (which they "cam" up out of the way, in order to pass by) causes a "washing away" or erosion of this portion of the tool.

In face-milling operations it has been found that erosion of the sides of the blades is frequently the principal factor in determining the life of the tool between grinds. Hence in this case any change in conditions resulting in a decrease in magnitude of the built-up edge will lengthen the life of the tool.

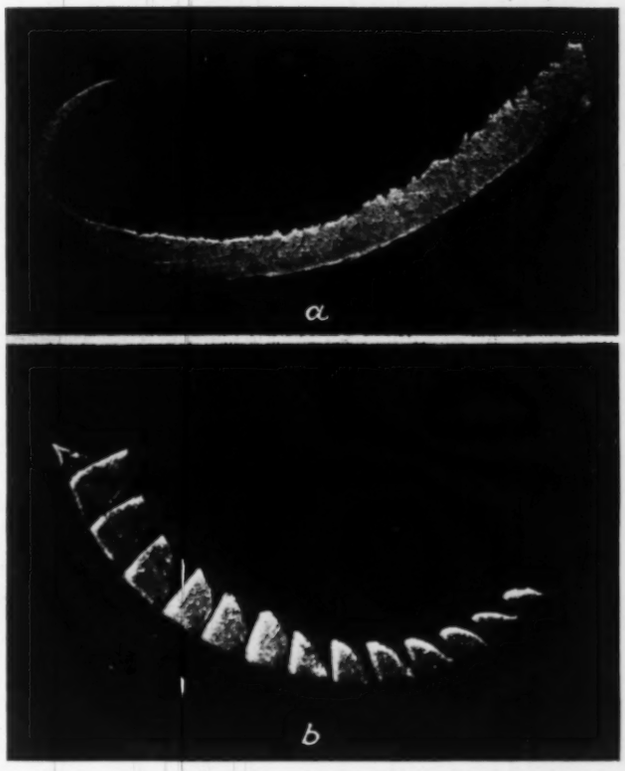


FIG. 27*a* and *b* COMPARISON OF MILLING CHIPS MADE UNDER NON-CHATTERING AND CHATTERING CONDITIONS, RESPECTIVELY

FIG. 28 PHOTOMICROGRAPH SHOWING STRUCTURE OF CHATTERED CHIP
(Note fan-shaped formation.)

CONCLUSIONS

In every metal-removing process the cutting tool induces high stresses, and consequent large deformations, upon the material which will finally form what is generally known as a chip. In this analysis it has been shown that, in this process, a well-defined distribution of stress is produced, and that a zone of highly worked material will develop into a shape which is similar to that of a cutting tool. This is known as the built-up edge. The contour of this built-up edge is determined by various factors, the principal one being the distribution of stress produced by contact between tool and work.

It has been definitely shown that the built-up edge is not an accumulation of particles of material gathered by the tool as it passes over the work but on the contrary is composed of the same material as the chip, and its formation begins immediately the tool comes in contact with the work. In many cases, however, it may not be carried to completion in the form in which we are accustomed to see it. This condition is well exemplified in the segmental-chip formation characteristic of relatively brittle work materials.

In cases where there is no apparent

discontinuity of flow, as in the so-called "flow" type of chip, the built-up edge adheres to the face of the tool, and by virtue of its location assumes the function of cutting, thus relegating the function of the tool to that of cutter support. Any discontinuity which may appear in the formation of the chip will affect the life of the built-up edge, but it will form again as soon as the discontinuity disappears.

The following factors act to decrease the magnitude of the built-up edge:

(1) A decrease in chip thickness.
(2) An increase in rake angle.
(3) An increase in tool sharpness.
(4) Application of lubricant to the tool face.
(5) Increase in cutting speed.

In heavy roughing cuts the built-up edge provides a protection for the extreme edge of the cutting tool, thus distributing the chip load over a greater area. On the other hand the existence of a large built-up edge permits the frequent escape of portions thereof underneath the cutting edge, thus producing a considerable erosion of this surface.

With a large built-up edge, the finished surface of the work presents a rough and torn appearance. This is because the continuity of the work surface is broken at frequent intervals by fragments torn from the built-up edge. Hence for production of the highest possible quality of finish, all conditions should be such as to reduce the magnitude of the built-up edge as much as possible.

The analysis of chip flow and formation of the built-up edge developed in this paper is presented as an introduction only. It is believed that the methods applied can be extended so as to lead to a proper evaluation of the variables encountered in metal cutting by studying their effects on the distribution of forces in the region of plastic flow in the neighborhood of the cutting edge. Photoelastic studies must be made to determine the exact changes in the shape of the stress-trajectory network with various tool angles; also with changes of contact area and depth of cut. This will permit the determination of the type of chip flow in accordance with the values of the various factors involved, and may lead eventually to the formulation of a mathematical theory of metal cutting.

By analyzing the stress distribution produced by a tool on the work material and investigating further the process of plastic deformation and rupture, it will be possible to bring into the realm of accurate analysis and control those factors which have been, and still are, so elusive in any cutting problem.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of Mr. C. Lovell, of the photographic department, to whom much credit is due for the motion pictures obtained in combination with the microscope. Also to Mr. S. Binns, and other members of the metallurgical laboratory staff for their assistance in the preparation of photomicrographs; and to the Union Twist Drill Company, of Athol, Mass., who supplied the milling cutters used in this investigation.

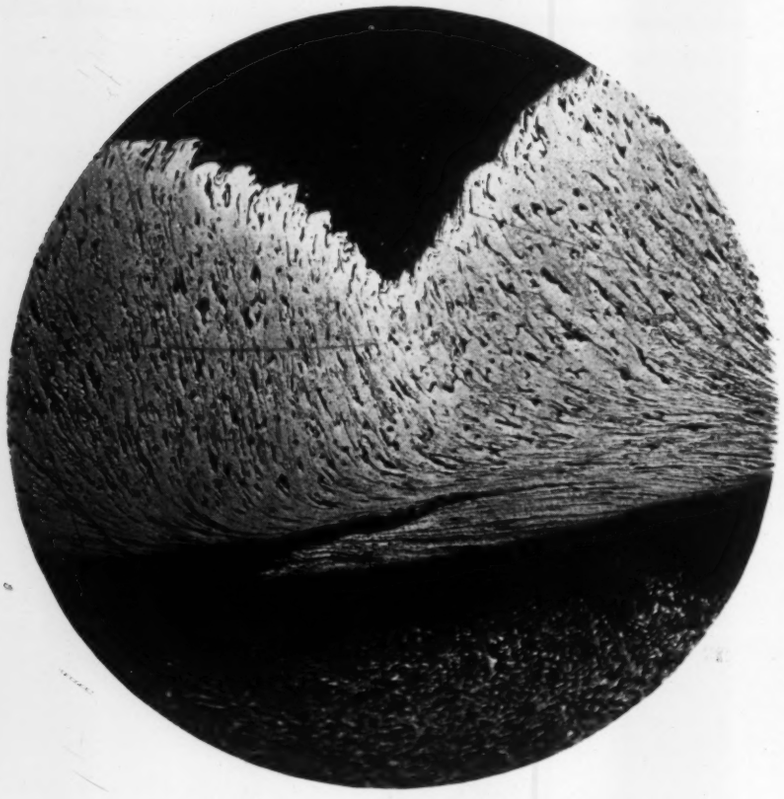


FIG. 29 PHOTOMICROGRAPH SHOWING STRUCTURE OF CHIP MADE UNDER CONDITIONS PRODUCING VERY SLIGHT CHATTER

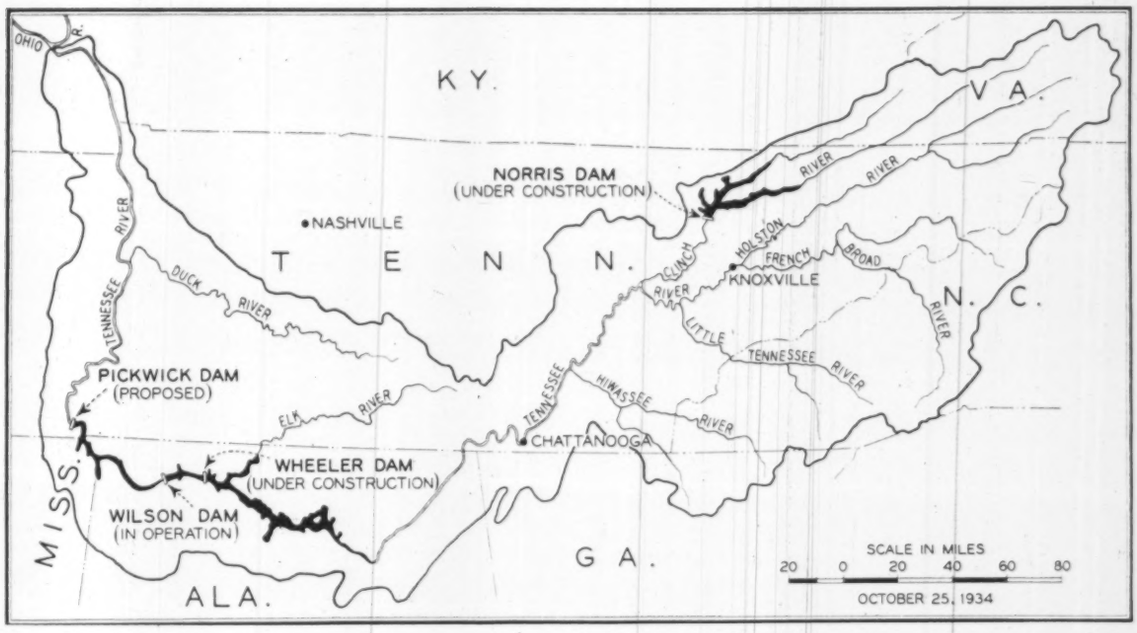


FIG. 1 MAP OF TENNESSEE VALLEY SHOWING LOCATION OF WHEELER POWER PLANT

45,000-HP PROPELLER TURBINE FOR WHEELER DAM

By F. H. ROGERS and R. E. B. SHARP

I. P. MORRIS DIVISION, BALDWIN-SOUTHWARK CORPORATION, PHILADELPHIA, PA.

THE Wheeler power plant, under construction by the Tennessee Valley Authority, is located on the Tennessee River 15 miles upstream from the present Muscle Shoals station near Florence, Ala. The dam now under construction has a total length of 6300 ft and comprises an overflow section of 2700 ft, a non-overflow section of 2842 ft, and a power-house section of 758 ft.

Fig. 1 is a map of the location, Fig. 2 a section of the power house through the first turbine, and Fig. 3 a section through the turbine. The final installation will consist of eight units, although, at present, but one unit is being installed. The turbine is rated at 45,000 hp under a net head of 48 ft, at a speed of 85.7 rpm, and is of the vertical-shaft, fixed-blade, propeller type, with volute casing and elbow-type draft tube formed in the concrete substructure. It is planned to have at least some of the future units of the Kaplan type, and the clearances and crane capacities are being designed with this in view.

COMPARISON WITH OTHER INSTALLATIONS

Before proceeding with a discussion of the design of this turbine, it may be of interest to compare it with other large turbines of this general type. Table 1 gives some of the relative dimensions and capacities of large propeller-type turbines built in this country and Europe.

Contributed by the Hydraulic Division and presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 17-21, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The Wheeler turbine, it will be noted, is the most powerful propeller turbine. The runner is larger than any yet undertaken on this continent, although there are four installations in Europe with larger runners, notably the Vargon unit containing a runner of 26.25 ft in diameter.

The Manitoba development (No. 7) is of interest in that it is believed to be the first high-head propeller-type unit to be installed in which the importance of runner-blade area was recognized. The initial installation was made early in 1923. The Shannon River development (No. 10) is also of special interest in view of the high head (106 ft) for which the turbine is designed.

ACCEPTANCE TEST

The discharge of the Wheeler unit at the rated full load is 9150 cu ft per sec. As the water passages are large, relatively short (see Fig. 2), and of changing cross-section from the intake to the volute casing proper, the difficulty of accurately measuring the flow in the field was recognized by the purchaser. The contract, therefore, calls for the building of a complete homologous model unit including racks, intake, casing, and draft tube, and the testing of this model in the manufacturer's hydraulic laboratory. The corresponding performance of the large unit is obtained from the test results of the model by stepping up the power developed by the model unit by the three-halves power of the ratio of the heads and the square of the ratio of the runner diameters. The efficiency of

TABLE 1 LARGE PROPELLER-TYPE TURBINES

Identification No.	Development	Manufacturer	Type	Horsepower	Head, ft	Rpm	Specific speed	Approx. runner diam, ft
1	Wheeler, U. S. A.	I. P. Morris	Fixed-blade propeller	45000	48	85.7	144	22.00
2	Safe Harbor, U. S. A.	I. P. Morris and S. M. Smith	Kaplan	42000	55	109	149	18.33
3	Ryburg, Germany	Voith	Kaplan	38700	37.7	75	157	22.97
4	Swir, Russia	Kristinehamn	Kaplan	37500	36.1	75	164	24.35
5	Seven Sisters, Canada	Dominion Eng. Works	Fixed-blade propeller	37500	66	138.5	143	16.25
6	Dogern, Germany	Escher Wyss	Kaplan	35500	35.1	75	166	22.97
7	Manitoba, Canada	Dominion Eng. Works	Fixed-blade propeller	28000	56	138.5	151	15.78
8	Vargon, Sweden	Kristinehamn	Kaplan	15200	14.1	46.9	211	26.25
9	Lilla Edit, Sweden	Kristinehamn	Kaplan	11200	21.3	62.5	144	19.03
10	Shannon, Ireland	Voith	Kaplan	33000	106	167	89	13.40

the large unit is obtained from the efficiency of the model unit by the well-known Moody formula

$$\text{Eff}_2 = 100 - (100 - \text{Eff}_1)(D_1/D_2)^{1/4}(H_1/H_2)^{0.01}$$

where subscript 1 applies to the model and subscript 2 applies to the prototype.

The efficiency of the model as used in establishing the efficiency differential will be the maximum value obtained from the test at whatever value of ϕ that may occur.

Table 2 shows the relation between values of efficiency as stepped up from model tests made in the I. P. Morris Laboratory, and the values obtained in the field. It will be noted that in all cases but one the stepped-up efficiencies are slightly lower than the field values. All of these units are of the fixed-blade propeller type.

In the I. P. Morris laboratory the power is measured by an electric dynamometer, the water flow by a calibrated weir, the head by a differential float gage, and the speed by an electrically actuated revolution counter.

TABLE 2

Runner diameter, in.	Model efficiency stepped up by the Moody formula	Field efficiency
133	90.9	92.0
86.81	92.2	93.6
92	91.0	91.0
93	90.6	91.0
72	91.2	91.0

MODEL UNIT

The model unit is an exact reproduction of the large unit in all respects from the intake racks to the draft-tube discharge. Fig. 4 is a side elevation of the completed model unit erected in the shop. The intake and volute casing are built of wood, lined with sheet copper to obtain smooth water passages. The draft tube is of cast iron. Fig. 5 is a view of the intake with the racks in place. The model runner is 16 in. in diameter and has six blades which may be set at various angles to determine the best blade position during the tests. The final tests on the model unit will be witnessed and checked by the engineers of the Tennessee Valley Authority, and these results, corrected as previously described, will be accepted as the performance of the large unit.

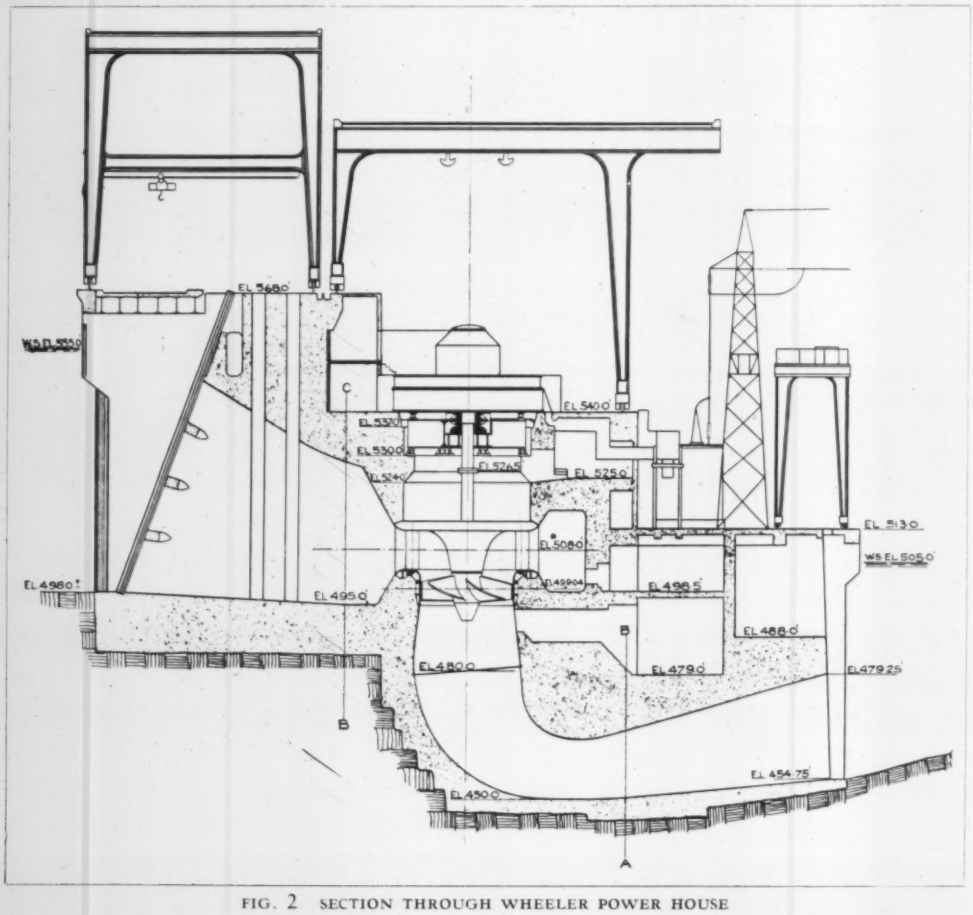


FIG. 2 SECTION THROUGH WHEELER POWER HOUSE

The advanced state of the concrete construction was such that the award of the contract for the turbine was made with a fixed location of the turbine centerline with respect to existing intake structure and existing downstream portions of the draft tube. Fig. 2, while not necessarily correct in all details, is sufficiently accurate to show the relation of the turbine to the remaining power-house structure. That portion of the structure which was fixed prior to the award of the turbine contract is to the right of *AB* and to the left of *BC*. The elevation of the bottom of the draft tube was fixed at 450. In the plan view the centerline of the turbine shaft is offset 3 ft from the centerline of the intake passages. There are two piers in the intake passage as well as in the downstream por-

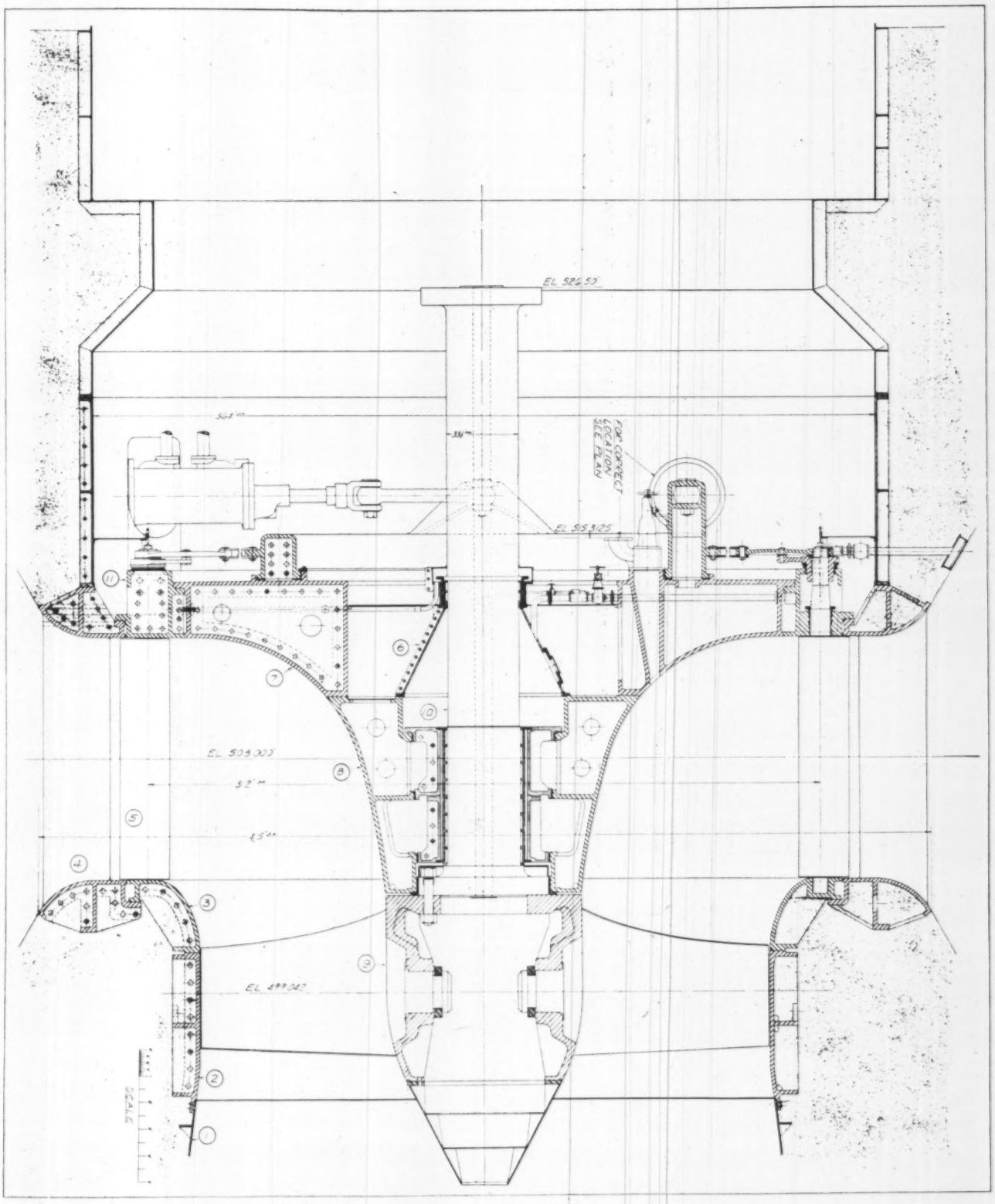


FIG. 3 SECTIONAL ELEVATION OF 45,000-HP TURBINE FOR WHEELER POWER PLANT

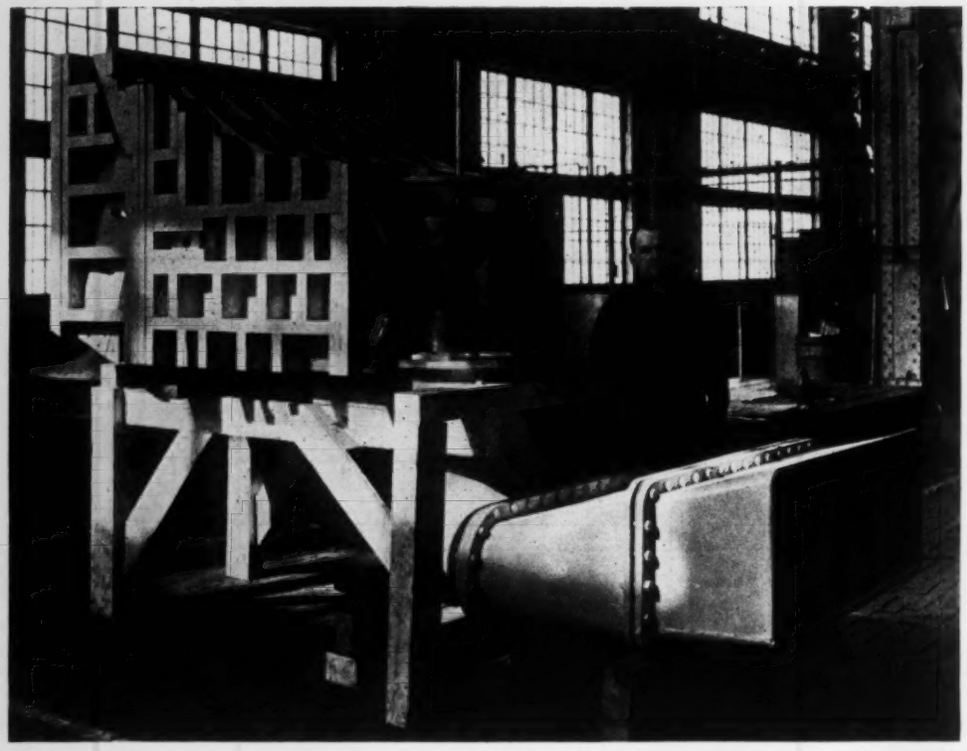


FIG. 4 MODEL UNIT IN SHOP

tion of the draft tube. The turbine contractor is responsible for the design of the water passages between *AB* and *BC*.

The tests made on the model have shown interesting results in connection with the alterations made in the vicinity of the casing baffle. Fig. 6 shows the model performance: (*a*) Without the floor or roof filler pieces shown and without the three vertical splitters; (*b*) with the floor and roof pieces added; and (*c*) with the vertical splitters added to the floor and roof pieces. It will be noted that the performance is virtually unchanged. The conclusion reached was that while the large water passage without the filler pieces or splitters may cause some tendency to eddy losses, it also permits the water to change its direction for entry to the stay vanes with very low velocity and small loss. The filler pieces, while probably reducing the eddy losses, increase the turning losses into the stay vanes, due to higher velocity. It was thought that the vertical splitters would reduce the turning losses. Had they shown any promise, further tests would have been made with splitters of revised design, and with the floor and roof filler pieces omitted.

SIGMA

One of the most important decisions in regard to the setting of a modern low-head hydraulic turbine hinges on the allowance provided to secure proper margin against pitting of the runner and adjacent parts due to cavitation. The TVA engineers wisely obtained from the various turbine manufacturers their recommendations for the elevation of the turbine with respect to tailwater, and in calling for bids allowed a zone of 5 ft for the elevation of the centerline of the turbine gates. The final elevation selected is 508, resulting in a value of sigma under the normal head of 0.799.

Sigma may be considered as the pressure-drop coefficient. It is the ratio of the possible pressure reduction at the elevation of the runner to reach the vapor pressure of the water, to the head on the turbine. It is expressed as $(h_b - h_s)/H$, where h_b is barometric water column, h_s the distance from tailwater to runner (usually taken to centerline of blades of a propeller runner), and H the head.[1]

It is, of course, desirable that the runner selected operate without pitting at the value of sigma which will exist at the plant, with some margin to spare. That is, the cavitation tests should show that the break in characteristics—horsepower, efficiency, and discharge—occur at a value lower than the plant sigma. One of the model runners under consideration for this turbine, loaned by the Dominion Engineering Works, has been tested for cavitation at the Shawinigan laboratory, and has shown no break in characteristics for a value of sigma as low as 0.6. This runner has also shown excellent efficiency.

Fig. 7 has been prepared to show how the value of sigma which exists at Wheeler compares with that at some other comparable installations. The points are plotted between specific speed and the plant sigma. A runner of a given specific speed has an allowable plant value of sigma which is dependent on the runner-blade design, the most important factor being the blade area. Therefore, there is no definite relation between sigma and specific speed for different designs. This fact coupled with wide variations in cavitation margins allowed, results in the wide scattering of the points shown in Fig. 7. However, increasing values of specific speed require increasing values of ϕ (= peripheral velocity $\div \sqrt{2gh}$) and decreasing blade area. Both of the latter conditions require, in turn, an increasing value of sigma. Point 9, it will be noted, is the Wheeler installation. A curve representing the average value of sigma for these installations has been drawn.

TURBINE DESIGN

Referring to Fig. 3 the plate-steel draft-tube liner piece (1), only partly shown in this figure, but completely shown in Fig. 2, extends 28 ft below the centerline of the turbine gates, to elevation 480. It is riveted to the throat ring (2) and is made of $^3/_4$-in. plate throughout with butt-welded sections, die formed to avoid abrupt changes in the contour.

THROAT AND DISTRIBUTOR RINGS

The throat ring is of cast steel and is in four sections, the upper portion cylindrically machined, and the lower portion taper machined to suit the flare (7 deg on a side) of the draft-

[1] "The Hydraulic Turbine in Evolution," by H. B. Taylor and L. F. Moody. Paper presented at the Hydroelectric Conference, Engineers Club, Philadelphia, Pa., 1922.

"Experimental Research in the Field of Water Power," by D. Thoma. Trans. First World Power Conference, London, 1924, vol. 2, p. 536.

"Inter-Relation of Operation and Design of Hydraulic Turbines," by F. H. Rogers and L. F. Moody. Paper presented at the Hydroelectric Conference, Engineers Club, Philadelphia, Pa., 1925.

tube liner. The distributor ring (3) is also in four sections and is made of cast steel. It is machined to an elliptical curvature from the gate circle to the top of the throat ring, this corresponding with an arc of a circle in the direction of flow at the most efficient gate opening.

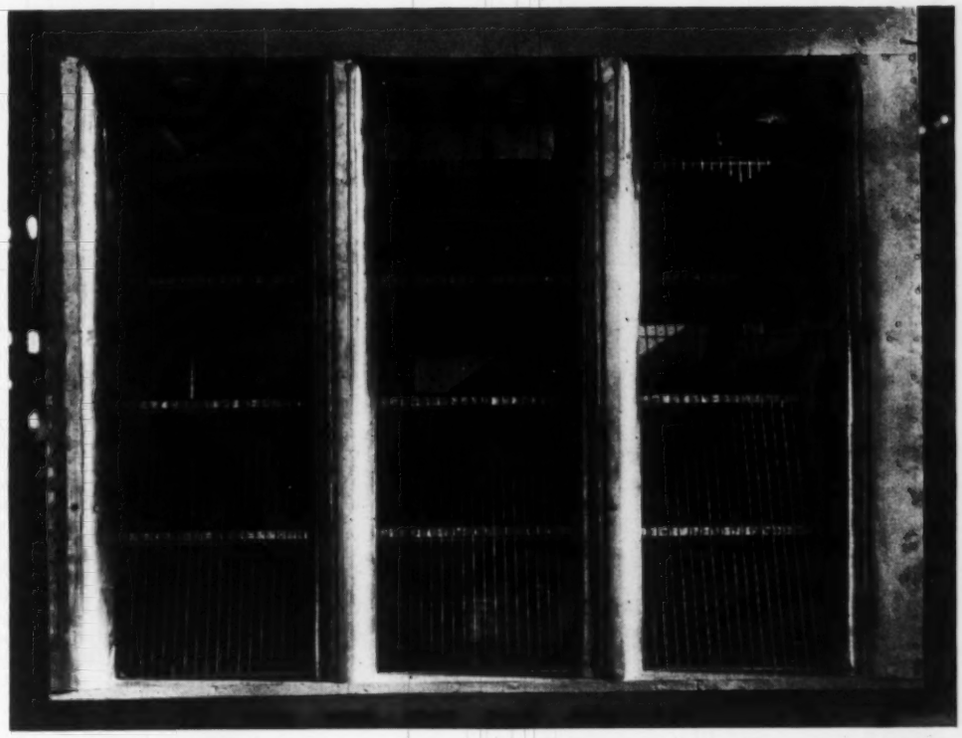


FIG. 5 MODEL INTAKE AND RACKS

STAY RING

The stay ring (4) is made of cast steel and has 12 vanes. It is split into six sections for casting and shipping. The heaviest load is taken by this member when the casing is empty, when the estimated weight carried is 7,200,000 lb, including generator, concrete, and a portion of the turbine. The center of the load is not at the shaft center, and this results in an estimated load of 800,000 lb on one of the vanes on the upstream side of the turbine. All vanes are of the same cross-section, except the baffle vane, and all are of sufficient strength to withstand the maximum column load imposed. The tension load in these members when the turbine is in operation is relatively low, due to the reduction occasioned by the superimposed weights.

GUIDE VANES

There are 24 gates, or guide vanes (5). This number has been found experimentally to give satisfactory performance as regards efficiency and to minimize the eddying tendency downstream. With a given diameter of gate circle there is less overhang over the distributer ring than with a smaller number of gates. The stems of the gates, both upper and lower, are cast integrally. The overall length is $160^1/_4$ in. The castings are poured with their longest dimension vertical. Unusual precautions are necessary to take care of the hydrostatic pressure in the lower portion of the mold. Two main requirements must be fulfilled in connection with the design of these vanes: (1) They must be efficient from a hydraulic standpoint; (2) under the maximum conditions of head which will be imposed the stresses in the vanes proper, as well as in the stems, must be within allowable limits—in this instance not more than 10,000 lb per sq in. Each vane is a beam with three points of support, the bearing at the lower stem, the intermediate bearing just above the vane proper, and the bearing at the upper end of the stem. Moreover, the sectional modulus throughout the length varies materially, this being a minimum at the lower end where the vane is tapered to a thin cross-section, and a maximum at the upper portion where it joins the upper stem. In analyzing the stresses in the vanes, the bending moments are determined by the construction of the usual funicular polygons, with consideration of reactions due to the hydraulic load and to the thrust at the upper end caused by the servo-motor forces. It is, of course, necessary first to determine the deflection with the intermediate point of support removed, and then to ascertain the deflection at this point with an arbitrary concentrated load. At the intermediate bearing the reaction equals the arbitrary load times the deflection with two supports, divided by the deflection caused by the arbitrary load. The stress is found to be a maximum in the stem just above the vane. The diameter of the stem is affected only slightly by the governor load, and mostly by the hydraulic forces. The maximum equivalent stress at this point is determined by the shear-energy theory, where $S_{eq.} = \sqrt{S_t^2 + 3S_s^2}$; S_t being the tension due to bending and S_s the torsional stresses.

HEAD COVER

During erection and dismantling the weight of the turbine revolving parts is taken by the conical support for the mainshaft stuffing box (6), and transmitted through the head cover to the stay ring. The inner head cover (7) is provided with four lugs by which this member, with the head-cover barrel (8) and the turbine revolving parts (9) and (10), may be lifted out of the turbine pit. Piece (7) is in halves, and the outer head cover (11), which remains in place during the aforementioned operation, is in quarters.

The design of the outer head cover must be such as to carry the downward load due to the weight of the parts indicated. Furthermore, this outer head cover must resist the upward pressure under pieces (7) and (8) as well as that under the outer head cover itself. These upward forces, for this turbine, are materially greater than the downward forces. Also the upward forces are alive and act during operation, whereas the downward force is static and occurs to the greatest extent during erection and dismantling. The necessary section modulus of this outer head cover is determined by the relation

$$M_1 = 2/\pi(W_1R_1/2) - 2/\pi(W_2R_2/2) = (W_1R_1 - W_2R_2)/\pi$$

$$M_2 = 4/3\pi(W_1R_1/2) - 4/3\pi(W_2R_2/2) = 2/3\pi(W_1R_1 - W_2R_2)$$

$$\text{Net moment} = (1/\pi - 2/3\pi)(W_1R_1 - W_2R_2)$$

$$= 1/3\pi(W_1R_1 - W_2R_2) = 2SI/C$$

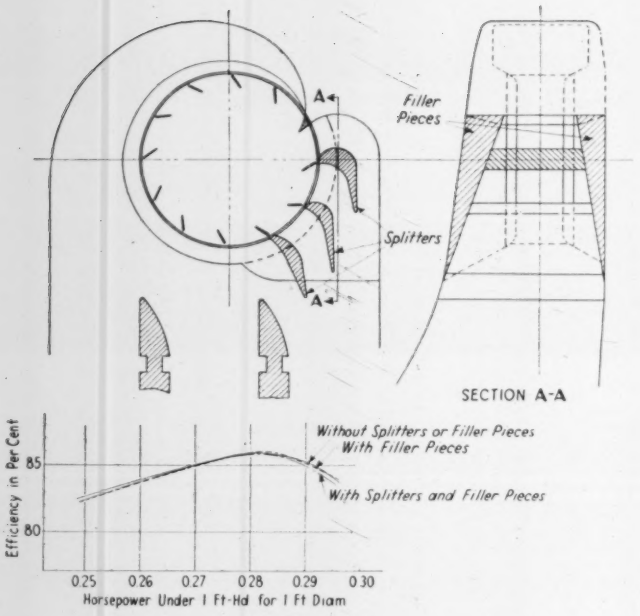


FIG. 6 TEST RESULTS OF CASING ALTERATIONS

$$I/C = (W_1R_1 - W_2R_2)/6\pi S$$

where M_1 = moment of flange loads on each half of outer head cover
M_2 = moment of pressure on face of each half of outer head cover
R_1 and R_2 = radii of outer and inner bolt circles
W_1 and W_2 = total of loads on outer and inner bolt circles for complete ring
I/C = sectional modulus of outer head cover
S = bending stress

As the four radial joints in this outer head cover are subject to the same load, the design thereof as regards size and location of bolts and of supporting flanges was given careful consideration.

BEARING

Of particular interest in the design of this unit is the main guide bearing which is of the Goodrich cutless rubber type. This type of bearing was first used in hydraulic turbines in 1924. The installations have been successful and have shown but little wear even in cases where lubricating water has carried sand or abrasive material. The bearings have proved far superior to the water-lubricated lignum-vitae bearings formerly used in wearing qualities, particularly where the abrasive matter was present in the water.

The rubber-type bearing also has advantages as compared with the oil-lubricated babbitted type from a viewpoint of operation, accessibility, and simplicity. An oil bearing requires a stuffing box between the bearing and the turbine runner, and this increases the overhang of the turbine runner, increasing the danger of vibration. Even in the case of large-size Francis turbines this stuffing box is rather inaccessible for adjustment and repacking, and for small Francis units and propeller-type units in particular the stuffing box is extremely inaccessible. With oil bearings, a lubricating pump must be furnished, located below the bearing, and in propeller-type units, drainage pumps must be provided to keep leakage water out of the oil supply.

With the rubber bearing no stuffing box is required so that the bearing may be located immediately above the runner, eliminating the undesirable overhang, and oil and drainage pumps are not required. The rubber bearing furnished with the Wheeler Dam is of the strip type illustrated in Fig. 8 which shows a smaller-size bearing. The rubber is vulcanized to extruded steel strips made of a special shape to interlock with each other. The end strips are secured to the housing with countersunk screws and dowels. This type bearing may be adjusted for wear by inserting a metal sheet of the desired thickness between the housing and metal strips. The steel strips are protected against corrosion by cadmium plating after the rubber is vulcanized to the strips.

Due to its large size ($37\frac{1}{2}$ in.) the bearing housing is divided into six sections to facilitate handling. Stainless-steel bushings are provided on the shaft opposite the rubber bearing to minimize wear and to prevent rusting when the unit is shut down. Two sources of water supply are furnished, the normal supply being taken from the casing and the emergency supply from a station pressure line. A specially designed flow meter is provided indicating the flow in gallons per minute to the bearing, and a low-flow alarm, electrically operated, gives the switch-board operator immediate notice if the flow falls below a safe limit.

RUNNER

The runner is of cast steel and the hub is separate from the six blades. The latter are held in the hub against centrifugal force by a fitted circular key in halves, and against turning on their axes by fitted radial dowels. The circular key takes a shear load due to the hydraulic forces acting on the blades, as well as the weight of the blades, during operation, thus relieving the blade stems of the bending moments that exist in runners of the Kaplan type in which the blades are moved during operation.

The casting of the blades and hub separately is necessary for this turbine, due to size, but this arrangement is advantageous in permitting more accurate setting of the blades than is possible with a single casting. It is expected that shipment will be made with the hub assembled with four of the six blades. The remaining two blades will be assembled on arrival at the plant site.

SHAFT

It is essential, of course, that the shaft diameter be ample from the standpoint of torsion, and also that the lowest critical speed be well above the runaway speed. The torsional stress at full load and normal speed must be such that the momentary stress resulting from synchronizing under the worst possible conditions will be below the elastic limit. The shaft is pro-

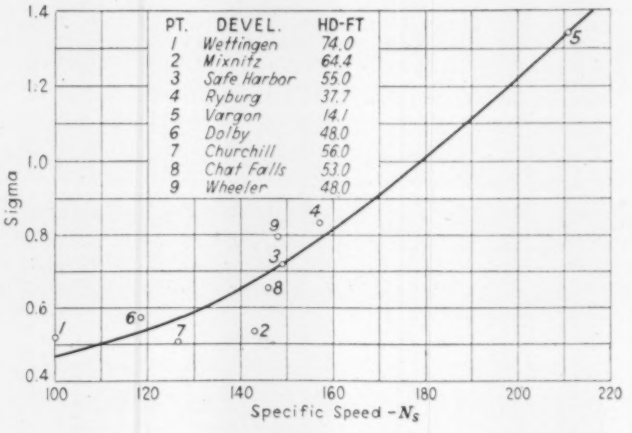


FIG. 7 RELATION BETWEEN SIGMA AND SPECIFIC SPEED

vided with an 8-in. hole through the center for inspection and heat treatment. At all points where change in shaft diameter occurs, adequate fillets are provided to prevent dangerous stress concentration.

It is found that critical-speed considerations do not affect the shaft diameter of this unit. While the distance between the turbine and lower generator bearing is 30 ft 9 in., the critical speed is found to be well above the estimated runaway speed of 190 rpm. The presence of an upper generator bearing, a relatively short distance between generator bearings, and the small amount of overhang of turbine runner below the turbine bearing are factors which maintain the critical speed at a high value.

RUNAWAY SPEED

The estimated runaway speed is 190 rpm at the maximum head that will obtain. There are two factors which tend to make the actual value less than that stepped from the model; (*a*) cavitation, and (*b*) greatly increased discharge which increases the differential between gross head and net head under this condition.

CRITICAL SPEED

It is found that critical-speed considerations do not affect the shaft diameter of this unit, as the lowest critical speed is well above the estimated runaway speed. The method used in determining this value, may be of interest.[2]

For simplification of the mathematical analysis the overhanging loads of the exciters were added to the weight of the generator rotor in such a proportion as to give an equivalent value of deflection. For the weight of the shaft between the lower and middle bearings a concentrated load equal to one half the value of the shaft weight was used, acting at the center of the span. The direction of application of this load was reversed with respect to the generator and runner loads (Fig. 9),

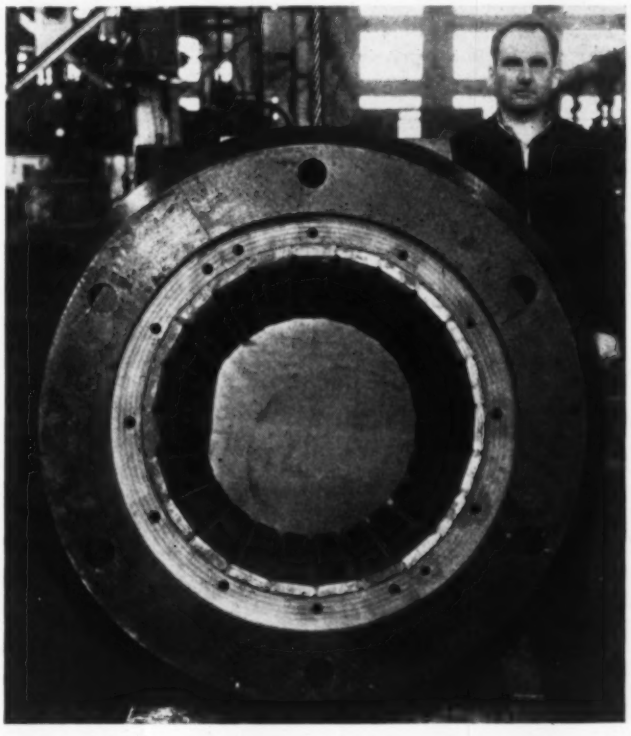


FIG. 8 RUBBER-LINED GUIDE BEARING

[2] "Lateral Vibration of Shafts," by Lewis F. Moody, *Product Engineering*, February, March, and April, 1935.

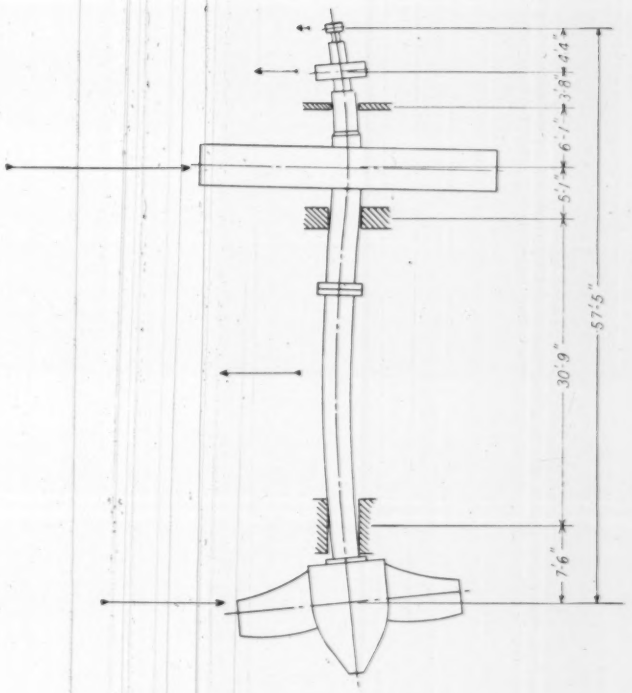


FIG. 9 CRITICAL-SPEED LOADING DIAGRAM

the critical speed being dependent on the maximum deflections which can be caused by a combination of loads.

As the first step the critical speed was calculated by the Rayleigh method as expressed by the formula $N_c = \dfrac{187.6}{\sqrt{\Sigma WY^2/\Sigma WY}}$ where W is the concentrated load at a point and Y is the sum of the deflections due not only to the load W at the point but also the partial deflections at that point caused by any other loads in the system. In order to solve the problem by the exact method which deals with dynamic rather than static deflections, the following cubic equation must be solved, this equation being for three loads only:

$$(Y - Y_{11})(Y - Y_{22})(Y - Y_{33}) - Y_{23}Y_{32}(Y - Y_{11}) - Y_{13}Y_{31}(Y - Y_{22}) - Y_{12}Y_{21}(Y - Y_{33}) = 2Y_{12}Y_{23}Y_{31}$$

where Y is the equivalent deflection and the values of Y with subscripts designate the partial static deflections of any load in the system at any of the points of application, the first number indicating the location where the deflection is being determined and the second number the number of the load producing the deflection. From the Rayleigh solution an approximate value of the equivalent deflection is obtained from:

$$Y = (\text{approx.})\ \Sigma WY^2/\Sigma WY$$

The exact value of Y is determined by trial from the cubic equation already given and the critical speed is expressed by the formula $N_c = 187.6/\sqrt{Y}$. By the Rayleigh method this value worked out as 639 rpm. By the exact method this became 588 rpm, a decrease of $8\frac{1}{2}$ per cent under the value allowed when calculated by the approximate Rayleigh method. The actual value of N_c tends to be greater than this value by the effect of the gyroscopic action of the generator rotor, and by the increased stiffness of the generator shaft due to the rotor hub. On the other hand, N_c is decreased by any deflection of the bearing supports and to a small extent (about 9 rpm) by the deflection of the rubber lining of the turbine bearing.

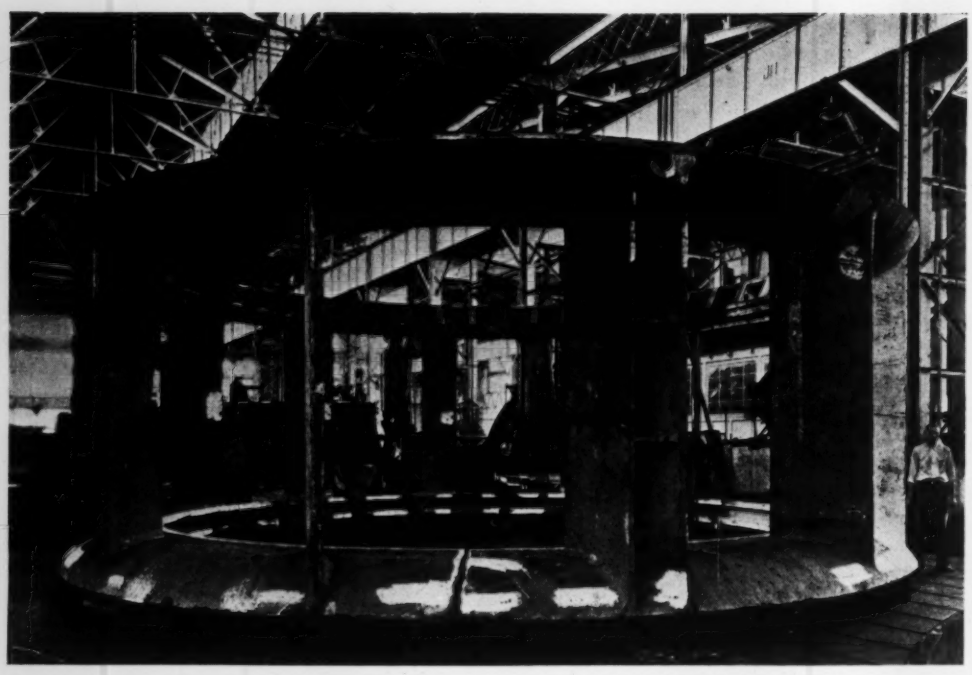


FIG. 10 ASSEMBLED STAY RING. OVERALL DIAMETER, 34 FT 7 IN. TOTAL WEIGHT 228,000 LB

It is planned to operate this unit at times as a synchronous condenser. This will require admitting air under pressure in order to lower the water level below the runner. An automatic air valve, actuated by the movement of the operated ring, and connected to a supply of compressed air, is provided for this purpose. This valve is designed to admit air also when the turbine is operated below about 60 per cent gate opening in order to improve the efficiency under that condition.

The leakage through the turbine gates when the turbine is shut down can be appreciably reduced by maintaining air pressure below the head cover with the water in the draft tube depressed to an elevation just above the roof of the draft tube in the discharge leg. With head-water level at 555, the head on the turbine gates at the centerline thereof (elevation 508) is equal to 47 ft. This assumes atmospheric pressure inside of the gates. If the level of water in the draft tube is depressed from elevation 505 to 470 (giving a seal of about 5 ft above the roof of the tube), this results in a back pressure of 35 ft on the turbine gates, reducing the net head thereon to 12 ft, or roughly one-fourth of the head otherwise acting. The amount of make-up air required to maintain this low water level has been found to be insignificant.

The authors are indebted to Lewis F. Moody and R. B. Willi in connection with the calculating of stresses and critical speeds; and to H. S. Van Patter, chief engineer of the Dominion Engineering Works, and S. Logan Kerr for the model tests.

FIG. 11 HALF INNER HEAD COVER. SHOWS TWO OF THE LUGS USED IN HANDLING ASSEMBLED HEAD COVER, SHAFT, AND RUNNER. WEIGHT 60,000 LB

AMERICA'S OUTPUT *and* INCOME

By DONALD S. TUCKER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SAVING, though necessary for the expansion of industrial plant, may, nevertheless, check that expansion. Three volumes, published recently by the Brookings Institution,[1] are devoted primarily to a discriminating and detailed measurement of America's capacity to produce, to consume, to save, and to invest its savings. These three volumes are tied together by the thesis that savings, in excess of productive investment, may be a cause of financial maladjustment. The argument (volume 3) runs as follows: The process of saving checks the demand for consumption goods. It thus checks the demand for capital goods, because the creation of new capital goods waits upon the demand for their products. Excess savings flow into wasteful or even harmful channels, such as unproductive loans abroad, speculative excesses, and the waste of capital through the consumptive spending of speculative profits. The striking event of the predepression era was not a reckless expansion of productive facilities but the relative rigidity with which the expansion of productive facilities was limited to the immediate demand for the product.

Overcapacity of plant exists now as a result of the world depression; but overcapacity was not a cause of this depression. In the years preceding 1929 there was no tendency for idle plant capacity to increase (Volume 1). In 1929 our industrial plant was operating on the average at 80 to 83 per cent of its practical capacity. To operate it at full capacity would have required a million additional workers. These could have been secured—but secured only at the cost of a painstaking and careful readjustment of our labor force. It would have been necessary, for example, to withdraw nearly half a million workers from agriculture and to train them for industrial labor. This withdrawal would have been difficult because of the intense need for occasional labor during certain brief intervals in the one-crop farming areas. We cannot shorten working hours materially and still produce the quantity of goods which Americans are accustomed to consume. Our desires and standards of living are already pressing too hard upon our productive capacity.

In certain industries it is true that serious overcapacity existed in 1929. These industries apparently were those in which (1) recent technical progress or recent changes in demand had temporarily destroyed the adjustment of capacity to demand, and sufficient time had not yet elapsed to permit readjustment, or, (2) conditions were highly competitive, business units were small, and investment occurred at times without adequate examination of the opportunity.

(1) Invention in some fields had rendered certain units obsolete (e.g., beehive coke ovens) and the obsolete equipment had not yet been fully liquidated. Improvements in methods, product, or changes in demand had in other fields made an unexpanded plant more than sufficient for current needs and there had not yet been time enough to permit readjustment of plant or demand. Automobile-tire manufacturers had idle plants because of recent increases in the durability of tires. Increased managerial efficiency had made our railroad plant more productive. Gross ton-miles per freight-train hour, for example, had increased 80 per cent between 1920 and 1931. The demand for railway transportation had not increased in proportion to this growth of effective capacity. Liquidation is always difficult and in many industries the precise adjustment of plant capacity to demand is impossible. In railroading, for example, there is no intermediate point between a single-track line and no railroad. Our railroads had, therefore, excess capacity.

(2) The influence of the degree of monopoly control and of the size of the business unit showed itself notably in coal mining. In bituminous-coal fields capacity continued to grow after the War. It reached a peak in 1923. Even in 1929 some 17 per cent of the capacity of active mines was not utilized and idle mines could have added another 17 per cent to the total output. Anthracite coal, however, displayed no such excessive development. Such overcapacity as existed in 1929 resulted directly from recent declines in the consumption of anthracite, not from any expansion of productive facilities. The most extreme example of overcapacity was found in agriculture where technical changes and small-scale investment had combined to create a great excess.

On the other hand, impending undercapacity is suggested sharply by the situation revealed in certain other industries. Rayon plants operated at 100 per cent of capacity even during much of this depression. Full-fashioned hosiery mills up to 1929 were operating often on double shifts. Printing and publishing houses operated at about 90 per cent of practical capacity during the years from 1925 to 1929. We know that plant capacity has been increased but little during the last five years. In many lines, therefore, an upswing of demand might now reveal serious undercapacity and cause sharp increases in the price of products. Even in 1929 our idle plant amounted to only 20 per cent of practical capacity and this 20 per cent must probably be regarded as the normal waste attendant upon competitive business in a changing world. Certainly this waste had shown no long-run tendency to grow from 1900 to 1929.

Could America consume an increased output if changes in our productive organization were to make an increased output possible? (Volume 2.) Unsatisfied wants are so pressing that mere increase in income without increase in population would cause huge increases in demand. The direction which these additional expenditures would assume depends, of course, upon the portion of our population which might receive the additional income. If the increase went entirely to the poorest 70 per cent of our families, raising these to the level of $2500 per year, the increases in consumption would be distributed as follows: food 40 per cent; shelter and home maintenance 65 per cent; clothing and adornment 65 per cent; other consumer's goods (including transport, education, health, and recreation) 115 per cent.

The wealthiest fifth of American families (those with in-

[1] "America's Capacity to Produce," by Edwin G. Nourse and Associates. Washington, The Brookings Institution, 1934. Cloth, $5\frac{1}{4} \times 8\frac{1}{4}$ in., 608 pp., $3.50.

"America's Capacity to Consume," by Maurice Leven, Harold G. Moulton, and Clark Warburton. Washington, The Brookings Institution, 1934. Cloth, $5\frac{1}{4} \times 8\frac{1}{4}$ in., 272 pp., $3.

"The Formation of Capital," by Harold G. Moulton. Washington, The Brookings Institution, 1935. Cloth, $5\frac{1}{4} \times 8\frac{1}{4}$ in., 207 pp., $2.50.

Fifth of a series of reviews of current economic literature affecting engineering prepared by members of the Department of Economics, Massachusetts Institute of Technology, at the request and under the sponsorship of the Management Division of The American Society of Mechanical Engineers.

comes in excess of $3100 per year) accounted for 98 per cent of our total savings. Only 2 per cent of our savings came from the 80 per cent of all families having incomes less than $3100 per year. For 80 per cent of American families expenditures tread upon incomes so closely that any increase in income to this group would result in an almost simultaneous expansion of purchases. Even for the wealthiest tenth of our population expenditures consumed more than 60 per cent of their incomes. America's capacity to consume is, therefore, determined substantially by its income. Even if great increases in income should give to lower groups incomes equal to those in the higher brackets, there is no reason to believe they would save more than those already in that position. We have not yet reached a stage in which it is possible to produce more than we would like to consume. Potential demand, though huge, can become actual demand only when supported by purchasing power or income. Sales of goods to Americans will increase substantially in proportion to American incomes.

Income from production is determined precisely (not substantially) by the value of the things we produce. Payments for goods become either profits or expenses, that is, income to business men or to others. Even "during the 'new era' of the gay twenties the United States was not living beyond its means." Some families, of course, lived beyond their incomes, but for the United States as a whole, what we have bought has been restricted to our power to produce.

To increase the consuming power of the American people we must (1) increase our productive capacity whether in plant or in personal skill; (2) reduce, if possible, the noncyclical waste, that is, the 20 per cent of idle plant capacity and of partially employed labor which existed even in 1929; and (3) reduce the losses of business depression. The third volume of this series is concerned primarily with the cyclical problem. It starts by contrasting saving with the formation of capital.

Savings, if invested, become income at the moment of investment. To the man who has saved $20,000 the erection of a store building is an investment of capital. To the building contractor, the carpenters, the bricklayers, and the sellers of building materials this $20,000 of savings becomes income the moment it is invested, i.e., paid out to them. If all savings were invested promptly, then if bank credit, and its rate of turnover remain unchanged, there would be income in the hands of some one to buy promptly the goods which are currently produced. Unfortunately, savings are not always invested promptly. Investment occurs only when an expansion in the demand for consumption goods makes new equipment seem necessary. Saving dries up this demand for products and prevents investment. The growth of a well-to-do middle class and the consequent growth of savings, especially after 1924, made this a serious problem.

Cyclical variations in the capital-goods industries accompany but are greater than variations in the consumption-goods industries. Where differences in timing have been observable, the consumption-goods industries have led the way. When consumption-goods industries expand, capital-goods industries expand greatly. When demand for consumption goods is curtailed, the demand for capital goods is curtailed greatly. Thus it happens that savings are not spent (invested) when they are made. Investment may occur either before or after saving. Savings may be invested before they are accumulated because of the operations of our banking system. In the credit expansions and contractions of commercial banks and especially in the variations of their security holdings and of their loans on securities, Moulton finds one of the conditions which permit cyclical depressions to occur.

The contrast between saving and investment is one which needs emphasis. Traditional economic theory has been too prone to assume that these two operations are substantially simultaneous. That assumption should no longer be possible. This reviewer would criticize the third volume for its failure to analyze the rôle of idle bank deposits and for its omission of some mention of liquidation which is at times a greater force than savings in destroying the equilibrium between production and consumption; but it is perhaps captious to criticize omissions. Three volumes cannot describe all factors; and the contributions of these three volumes are significant. One of these contributions is perhaps open to some question. In 1911 Mr. George Hull published a book, "Industrial Depressions," in which he maintained that the changing prices of construction materials were an important cause of changes in the volume of construction. When prices of construction materials get low enough during depression, they arouse, he maintained, the bargain-counter instinct and stimulate construction. Such construction, of course, would stimulate the expansion of loans by commercial banks (and the return of idle savings to the income stream). Professor Moulton, on the other hand, maintains that construction of productive plant is a function of the demand for consumption goods. He states, however, that it is not necessary to assume that recovery must always start from the side of consumption goods. His evidence that recoveries in the past have chiefly so started is, nevertheless, impressive.

These three books were not written as an investigation into the causes of business cycles. They attempted an analysis of the relation of the distribution of income to economic progress. For this purpose an investigation of the facts of American economic life was made and this investigation secured the data upon which students may base answers to the questions raised by current ideas that depression results from low wage rates, or savings, or excessive production, or excessive productive capacity. The need for such factual material has been accentuated by recent business and political activity in restraining both current production and expansion of plant capacity. Volumes 1 and 2 of this series are primarily factual; but the facts presented give evidence that although financial maladjustments are a serious problem, there is as yet no great long-run excess in productive plant. What America needs is greater capacity to produce.

Our productive plant can be called excessive only if we blame it because its increase has permitted increased production, increased income, increased consumption, and increased savings, and because some portions of these savings have been used unproductively. It is this unproductive saving, not productive investment, which causes financial maladjustment. Economists agree that the increase in productive capacity due to some savings would not of itself cause depressions. Professor Moulton contends further that depressions may be caused if other savings both fail of productive investment and prevent it.

For those who are interested in the facts of American economic life for other reasons, these volumes will prove useful. In no other single place is there available such a wealth of recent material on our productive capacity in various lines, on our national income, its functional, geographical, personal, and family distribution, and on the ways in which that income is spent. Some of the books reviewed in this series have been important only because of the popularity of the errors which they propound. Here are three books whose style is popular, but whose importance lies rather in their reliable and scholarly character. The third volume, a contribution to economic theory, may seem rather more controversial to some economists than it does to this reviewer. All three volumes, however, are well worth careful perusal.

THE CINCINNATI MEETING

An Attendance of 800 at the A.S.M.E. Semi-Annual Meeting Recalls Former Times

AN UNDERCURRENT of feeling that better times are on the way seemed to pervade the Semi-Annual Meeting of The American Society of Mechanical Engineers, held at Cincinnati, Ohio, June 17 to 21, with headquarters at the Gibson Hotel. At least one observer found evidence of such a feeling in casual conversations, in what seemed to be better attended technical sessions with their spirited discussions, in the hospitality of the Cincinnati members of the Society who provided so generously for the comfort and entertainment of visitors and guests, and, perhaps as much as anything, in the registered attendance of 800, proof in itself of a returning tide of interest and enthusiasm among engineers for the technical progress of their profession.

The first two days were given over to meetings of the Committee on Local Sections on Monday and of the Council on Tuesday. Technical sessions began on Wednesday morning and continued through Friday afternoon, and on Saturday a number of those in attendance at Cincinnati traveled on to Knoxville to meet with members of the Knoxville Section and the Tennessee Valley Authority, in an inspection of the Norris Dam under construction across the Clinch River, and the de luxe construction camp at the town of Norris where workers and officials of the TVA associated with the project are living.

An account of the meeting of the Council, which sat through the morning, afternoon, and evening of a hot and humid day, its deliberations accompanied by the monotonous whir of electric fans, will be found elsewhere in this issue. No item of scheduled business was left unnoticed; and with the unremitting insistence of President Flanders the budget for 1935-1936 was successfully balanced. The budget will be found on page 531 of this issue.

TECHNICAL SESSIONS

As was to have been expected at a meeting held in one of the great centers of the machine-tool industry, subjects related to the industry were prominent on the technical program. Inasmuch as the complete program, substantially as the events themselves were unfolded at Cincinnati, was published in the June issue of MECHANICAL ENGINEERING, a repetition of it will not be attempted. While final plans on publication of the papers are incomplete, the following résumé will be of some assistance.

Three papers on education and training for the industries, by Herman Schneider, William F. Patterson, and J. F. Kolb, were printed in MECHANICAL ENGINEERING for July. No decision has been reached on the publication of six papers on materials handling. It is hoped that the interesting group of papers on "prefabricated housing," which drew a large attendance, may be reviewed in an early issue of MECHANICAL ENGINEERING. A few preprints of the paper by Thomas D. Perry are available.

Of the papers on hydraulics, that by R. V. Terry and D. G. Moorhead was printed in MECHANICAL ENGINEERING for May, and that by F. H. Rogers and R. E. B. Sharp will be found in this issue. Preprinted copies of two papers on drying, one by J. L. Carruthers and another by A. Weisselberg, are available. It is expected that the papers on waste elimination, by J. Q. Salisbury and Thomas H. Owens, will appear in extended abstract in an early issue of MECHANICAL ENGINEERING.

Six papers presented under the auspices of the Power Division, have already appeared in the Transactions, as follows: Those by Adolf Egli and James E. Mulligan in the April issue, and those by F. F. Fisher and E. T. Cope, Linn Helander, Sergei D. Mitereff, and S. W. Spielvogel and S. Kameros in the May issue.

It is hoped that space and funds will be available to publish at a later date much of the very interesting and significant contribution of the Management Division in the papers on quality control in manufacturing.

Of the papers on lubrication, that by H. A. S. Howarth has already appeared in the Transactions for May. Of the Fuels Division papers, that by H. O. Croft and C. F. Schmarje will be found in the Transactions for April, while J. H. Strassburger's paper was printed in MECHANICAL ENGINEERING for June.

The Machine Shop Practice Division held several sessions, including one in cooperation with the Railroad Division. Preprints of the paper by O. W. Boston, W. W. Gilbert, and C. E. Kraus, and those by A. Sellers, Jr., and L. D. Freeman are available.

F. N. Speller's paper, a contribution of the Iron and Steel Division, was published in MECHANICAL ENGINEERING for June. It is expected that the paper by R. E. Johnson and R. F. Gagg, contributed by the Aeronautic Division, will be published soon.

Elsewhere in this issue will be found the two addresses delivered at Cincinnati, the Calvin W. Rice Memorial Lecture, delivered by Adolphe Meyer, and that by Irving Langmuir, Holley Medalist for 1934.

Two papers delivered at the session devoted to power transmission have been published, that by G. M. Bartlett in the April issue of Transactions, and that by R. R. Tatnall in the May issue of MECHANICAL ENGINEERING.

GRAPHIC ARTS

Among the most popular sessions at the Cincinnati meeting were those held by the Graphic Arts Division of the Society in connection with the new Graphic Arts Research Bureau. The session on Thursday consisted of a series of lectures on the fundamentals of color, with special application to printing in the graphic arts. On Friday the lithographic session was held at the University of Cincinnati. In the morning, Robert Reed, of the University of Cincinnati and director of the Lithographic Technical Foundation, discussed the lithographic research program of the research foundation. The paper on electrotype metals by Samuel Epstein, of the Battelle Memorial Institute, replaced one previously announced on lithographic metals by Lewis Kantrowitz. Mr. Epstein discussed some interesting research work that had been done for Ohio electrotypers. He produced some interesting conclusions as a result of the research work, and pointed out the possibility of securing support there for research work in printing metals. The Graphic Arts group had luncheon at the University and visited its research laboratory before the afternoon session.

Four papers were presented Friday afternoon, two for discus-

IRVING LANGMUIR
HOLLEY MEDALIST FOR 1934

sion and two by title. The papers presented for discussion were "Recent Photo-Mechanical Developments," by A. Mertle, "Printing of Color on Daily Newspapers," by H. M. Tillinghast. Both papers called forth lively discussion. The papers listed for presentation by title were by W. C. Huebner, for which time permitted only a brief discussion, and by W. G. Dodge and William Baumrucker, which discussed briefly an interesting problem in newspaper printing.

Preprints of the papers by R. F. Reed, A. Mertle, W. C. Huebner, Wm. Baumrucker and W. G. Dodge, and H. M. Tillinghast are available.

GRAPHIC ARTS RESEARCH BUREAU

The Graphic Arts Research Bureau, which was formed from the activities of the A.S.M.E. members of the Graphic Arts group at its conference last October in Philadelphia, held its first official meeting in connection with the A.S.M.E. Semi-Annual Meeting. The Bureau adopted a constitution which permits four types of members—company, association, individual, and research fellows. Three graphic-arts associations have already affiliated with the Bureau under organization membership rules. The Bureau has approximately 400 individual members, about one-quarter of whom are A.S.M.E. members. The Bureau decided to continue the present organization committee, the officers of which are: A. C. Jewett, Pittsburgh, chairman; Edward Epstean, New York, vice-chairman; and V. W. Challenger, Philadelphia, secretary and treasurer. It tentatively approved of the plans of the technical committee to hold the next Graphic Arts conference at Washington, D. C., in March, by which time it is expected that the new constitution adopted at the Cincinnati meeting will be put into effect. The Bureau unanimously voted to affiliate with the A.S.M.E. as it was the opinion of the officers that close alliance with the A.S.M.E. would be of tremendous benefit in the stimulating and carrying out of research projects.

SOCIAL EVENTS

The first of the many enjoyable and largely attended social events was a luncheon on Wednesday noon with George A. Seyler presiding, at which Cincinnati's witty mayor, Russell Wilson, delivered a greatly applauded address of welcome. Not to be outdone in a machine-tool center, President Flanders responded in a singularly happy manner which showed his mastery of this form of public address and a keen knowledge of the City of Cincinnati.

At the Thursday luncheon, Past-President Potter presiding, it was a great treat to hear a well-delivered, persuasive, and highly informative address on city government by Clarence A. Dykstra, city manager of Cincinnati. Mr. Dykstra pictured government as a system of public services, which, under a city manager, substituted management for the spoils system that is the usual accompaniment of too much local politics, and under which inefficiency increases costs. He spoke of the effect of the spoils system in the purchasing of city supplies and in contracting services, and showed how more efficiently, honestly, and effectively purchasing and contracting were carried on under a competent city manager. He made a particular point of regarding taxation as a bill for public services.

On Wednesday night the thoughtfulness of the Cincinnati Committee in providing entertainment met with competition in the form of a protracted business meeting and inclement weather. While the ladies and some members were able to take the boat ride to Coney Island on the *Island Queen*, those who attended the Business Meeting were forced to follow by bus. Clouds obscured the moon, but the dancing was enjoyed, and visitors from the East had an opportunity to observe the different trend which the evolution of steamboat design has taken on inland rivers as compared with the Atlantic seaboard.

Friday's luncheon, with Prof. C. A. Joerger presiding, provided an opportunity for F. M. Feiker, executive secretary of the American Engineering Council, to deliver a first-hand account of the Council's work at Washington and to cite as examples several instances in which his office had been of immediate and invaluable service to engineers remote from that city.

Announcement of the Nominating Committee's choices for president, vice-presidents, and managers, to be voted on this fall, were read by Secretary Davies. The names of the candidates and their biographical sketches will be found on pages 527 to 530.

It being the closing formal function of the meeting, John A. Hunter, of Boulder, Colo., presented, amid applause and eloquently seconded by Prof. Chas. E. Fuller, of M.I.T., a resolution of thanks to the Cincinnati Section for its able conduct of the meeting and its gracious hospitality.

THE BANQUET

Thursday's banquet at the Hotel Gibson provided a wide variety of entertainment to suit all tastes and ably demonstrated the supreme skill of the Cincinnati Local Section in pleasing everybody.

John T. Faig acted as toastmaster. Of tremendous interest to all Society members was President Flanders' address on Society problems which he has called "The Engineer, His Society and His Profession," and which will be published in MECHANICAL ENGINEERING early in the fall.

Speaking for the Committee on Awards, W. L. Batt announced the Holley Medalist for 1934, Irving Langmuir, of the General Electric Company, and introduced Harvey N. Davis, who listed, with rare skill and charm, the accomplishments of the medalist. The presentation of the medal was by President Flanders, and Dr. Langmuir's response took the

form of a brief address on "Mechanical Properties of Matter," which will be found elsewhere in this issue.

The Holly Medal was instituted and endowed in 1924 by George I. Rockwood, past vice-president of the A.S.M.E., to be bestowed for some great and unique act of genius of engineering nature that has accomplished a great and timely public benefit. The award has been made three times; in 1924 to Hjalmar Gotfried Carlson, for inventions relating to drawn-steel booster casings for artillery ammunition; in 1928 to Elmer Ambrose Sperry for inventions, including the gyroscope, that have freed navigation from the dangers of the fluctuating magnetic compass; and in 1929 to Baron Chuzaburo Shiba for contributions to aerodynamics and the development of ultra-rapid kinematographic methods.

The award to Dr. Langmuir was made in 1934, but, on account of his absence from the country last December, the presentation had been postponed. The medal was presented for Dr. Langmuir's "contributions to science and engineering, especially in the development of the gas-filled incandescent lamp, of the thoriated filament for thermionic emission, of atomic-hydrogen welding, of phase-control operation of the thyratron tube, and in fundamental research in oil films."

The serious business of the evening out of the way, President Flanders asked to have brought before him E. W. Burbank, of Texas, envoy extraordinary of Texan members of the A.S.M.E., who had brought their invitation for the Society to meet in Dallas in June, 1936. President Flanders, in a witty speech, explained that Mr. Burbank had been enjoined by telegram from his constituents to "bring back the bacon," and as evidence that he had done so, presented him with a box of what appeared to be this familiar comestible but in the form of a confection which, for some reason, is disguised locally to look like strips of bacon.

Followed then a floor show whose participants were children of undoubted talent, comprising an orchestra, dancers, an amazing contortionist, and singers of popular ditties. The enthusiasm with which these youngsters put on their acts and the zeal with which they played their instruments were infectious. Proof of their more normal characteristics was demonstrated afterward, when they attacked, with equal zeal, the ice cream provided by the master of ceremonies, George A. Seyler.

THE BUSINESS MEETING

The principal item of business at the business meeting, on Wednesday afternoon, was discussion of and action on changes to the Constitution affecting A.S.M.E. membership grades. These changes had been suggested by the Committees on Policies and Budget and on Membership, and had been reviewed by the Committee on Constitution and By-Laws, whose chairman, H. H. Snelling, presented them for discussion at the meeting.

The need in the Constitution for a restatement of membership grades has been given particular force by the recommendation of the Engineers' Council for Professional Development that the major engineering societies adopt uniform grades of membership, four in number, i.e., student-member, junior, member, and fellow. These grades, it was pointed out by the E.C.P.D., are logical steps in the engineer's development to professional security. A fifth grade, associate, and the honorary member are also provided in the proposed A.S.M.E. membership grades.

Discussion of the proposed amendments was frank and thorough, and as each paragraph was read it was either accepted or modified to make it acceptable to a majority present. In the form in which they were approved at the Business Meeting, the amendments to the Constitution will be sent to members for letter ballot late this summer and will be voted prior to the Annual Meeting in December. Changes in the By-Laws and Rules, necessitated by these amendments of the Constitution, will be made, as provided, by the Council on the adoption of the constitutional changes. Text of the proposed amendments to the Constitution will be found on page 532.

ADOLPHE MEYER
RICE LECTURER

WOMEN'S PROGRAM

Especial credit and commendation are due those who arranged the special program for the enjoyment of the ladies, about sixty in number, who attended the meeting. In addition to the social events participated in by the men, sightseeing tours of the city, including the new unique and beautiful Cincinnati Union Terminal, the University of Cincinnati, the city's parks, its shopping district, the Rockwood Pottery, and the Cincinnati Art Museum were provided for the ladies and thoroughly enjoyed by them. The Women's Committee, which displayed a more than customary hospitable concern for the comfort and entertainment of the visitors, was under the chairmanship of Mrs. W. W. Tangeman. Serving on the committee with Mrs. Tangeman were Mrs. R. E. LeBlond, Mrs. J. T. Faig, Mrs. George A. Seyler, Mrs. C. A. Joerger, Mrs. C. L. Koehler, Mrs. O. E. Hilmer, and Mrs. W. E. M. Fielman.

PLANT VISITATIONS

The industrial activities of Cincinnati afforded abundant opportunity for members attending the meeting to visit many plants engaged in a wide variety of work. Among the plants for which inspection trips were arranged are the following: Crosley Corp.; Lunkenheimer Co.; Queen City Steel Treating Co.; American Can Co.; Cincinnati Grinders, Inc.; Cincinnati Milling Machine Co.; R. K. LeBlond Machine Tool Co.; Cincinnati Water Works; Emery Industries; Procter and Gamble; Werk Soap Co.; Baldwin Piano Co.; Chas. Taylor Sons Co.; Lodge and Shipley Machine Tool Co.; American Book Co.; Strobridge Lithographic Co.; American Rolling

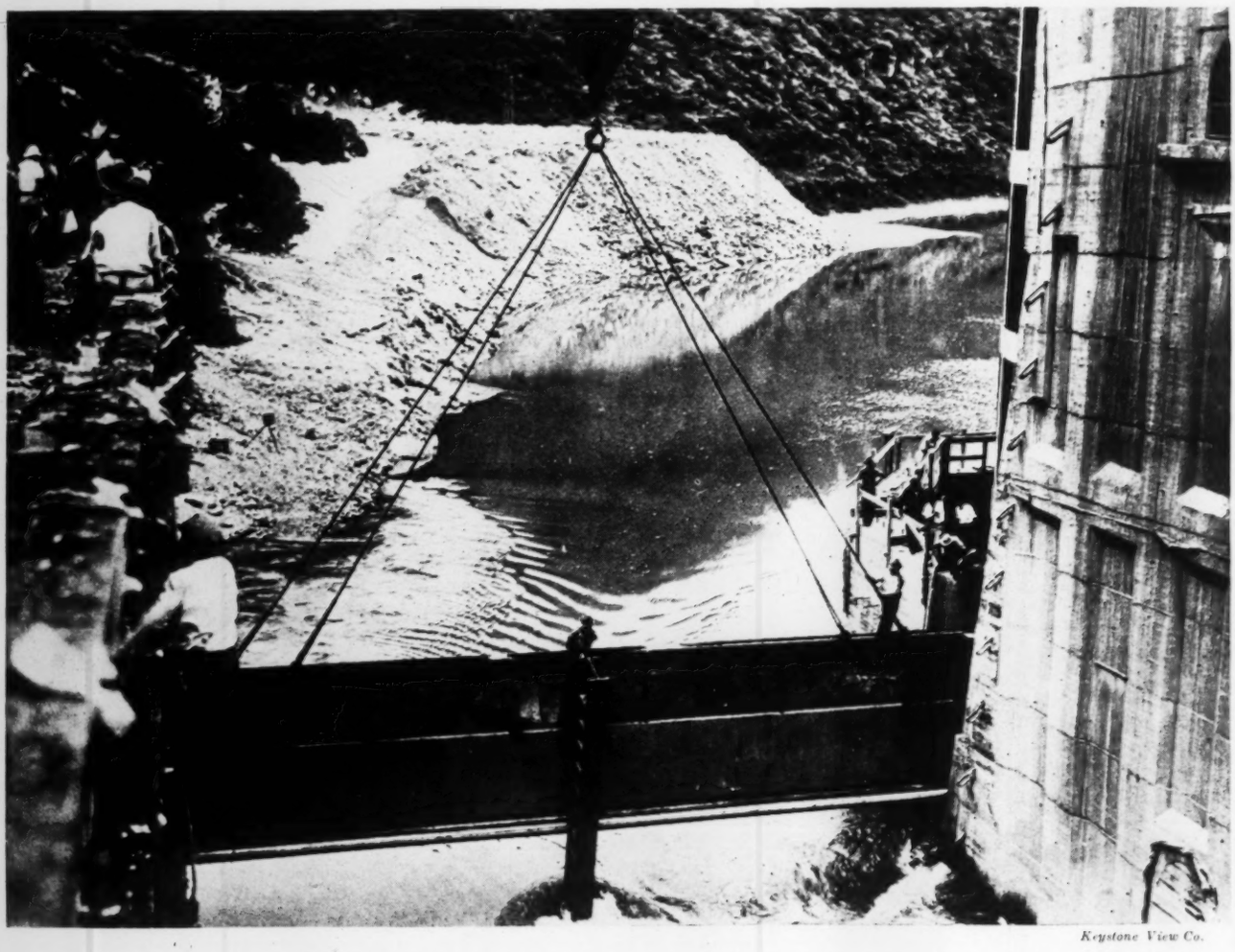
Mill, Middletown, Ohio; Cincinnati Bickford Tool Co.; Cincinnati *Times-Star;* Norwood Sash and Door Co.; International Printing Ink Co.; Champion Coated Paper Co., Hamilton, Ohio; Union Gas and Electric Co.; Alvey Ferguson Co.; American Tool Works; Heekin Can Co.; Methodist Book Concern; and Cincinnati *Enquirer.*

CINCINNATI COMMITTEES

Although the Semi-Annual Meetings of the A.S.M.E. are conducted under the supervision of the Committee on Meetings and Program, with technical papers contributed by the Society's professional divisions and research committees, their success depends largely upon the manner in which the local section, in this case at Cincinnati, cooperates in setting up the program and in attending to thousands of details. The General Committee, under the chairmanship of John T. Faig, consisted of Messrs. C. A. Joerger, George A. Seyler, C. L. Koehler, H. C. Uihlein, J. W. Bunting, W. E. M. Fielman, F. S. Dewey, R. S. Parker, F. E. Cardullo, W. W. Tangeman, E. A. Muller, O. E. Hilmer, and C. H. Anderson.

NORRIS DAM

The perfect summer day that followed, on Saturday, the cool and inclement weather at Cincinnati was an ideal one in which to penetrate the Cumberland mountains and inspect the great dam arising across the Clinch River not far from Knoxville. Those who left Cincinnati by train were met Saturday afternoon at Coal Creek by hospitable members of the Knoxville Section of the A.S.M.E. and the Tennessee Valley Authority, under the leadership of W. R. Woolrich and John P. Ferris, and conducted over the mountain to the damsite. Here, following an address of welcome, an opportunity was provided to view the crushing plant and cableways, and to look down upon the great masses of concrete that are rapidly developing into a dam 253 ft high, 210 ft thick at the base, and 1800 ft long at the crest. Crossing the river below the dam, the foundations of the power house and the welded penstocks were inspected at close range, following which the entire party, including many members of the Society for the Promotion of Engineering Education en route to Atlanta, assembled in the recreation building at the Town of Norris, four miles from the dam, where workers and supervisors live. David E. Lilienthal, one of the directors of the Tennessee Valley Authority, was introduced by John P. Ferris and spoke on the problems of the TVA and its numerous objectives. A motion picture was shown to depict some of the expected benefits of the extension of the use of electricity, of soil erosion and river control, and other purposes for which the TVA was authorized.



Keystone View Co.

WORKMEN BLOCKING WITH A STEEL GATE ONE OF THE OPENINGS IN THE NORRIS DAM OF THE TENNESSEE VALLEY AUTHORITY

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Motor Glider Maikafer

AT THE start a glider has to be pulled by some means until it develops a sufficient velocity to maintain itself in the air. As this method of starting involves considerable expense, a glider has been developed with an auxiliary motor to be used for starting purposes only, as well as to enable the glider to rise under its own power to desired elevations.

The German Experimental Institute for Gliding, at Darmstadt, has developed the Maikäfer water glider equipped with a Köller two-stroke-cycle motor having an output of 17 hp and weighing 21 kg. The glider itself has a width from tip to tip of 14 m and lifting surface of 17.5 m. Its total weight in flight is 320 kg. The load is 18.3 kg per sq m and 18.8 kg per hp. It has a cruising velocity of 90 km per hr. (*Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 3, January 19, 1935, p. 67)

AGRICULTURAL ENGINEERING

Mechanization of Farming

BEFORE the World War, the growth of the farm-machinery industry accompanied the development of improved horse-drawn implements and harvesting machinery driven by stationary steam and gasoline engines. In an expanding agricultural market, these products sold in an ever increasing volume. During most of the post-war period up to the depression, however, there was little increase in gross farm income, and the expansion in domestic equipment business was almost wholly due to the steady growth in tractor use. With like tendencies occurring in export markets, the tractor alone accounted for approximately 38 per cent of the industry's total value output in the three-year period 1928–1930.

Accompanying the rise in tractor power has been a corresponding contraction of aggregate horsepower on farms, as indicated in Table 1.

Since 1930 the number of horses and mules has declined further to 16,622,000 on January 1, 1935, intimating that the mechanical revolution of the twenties is continuing during the present decade. Present farm economic conditions are aiding rather than opposing this trend. Hence, the accumulating power shortage in agriculture doubtless will be met through purchase of tractors rather than by replenishment of horse and mule population.

TABLE 1 RATED POWER AVAILABLE ON FARMS

Source: U. S. Dept. of Agriculture

Horses and mules	1920	1930
Number	25,748,000	19,050,000
Horsepower[a]	20,970,000	17,171,000
Per cent of total power	56	24
Tractors		
Number	245,370	920,378
Horsepower	4,922,000	22,001,000
Per cent of total power	13	31
Trucks		
Number	139,000	900,000
Horsepower	2,783,000	22,510,000
Per cent of total power	7	32

[a] Adjusted for animals under two years old. Other souces contributed remainder of total power.

Making a liberal allowance of 10 years for average tractor life, it is evident that the 920,000 tractors on farms in 1930 will have to be replaced by 1940. Because of restricted sales during the first half of the present decade, it is roughly estimated that replacement volumes alone must average 125,000 annually over the next five years, or about 50 per cent greater than the indicated 1934 total. (*Standard Trade and Securities*, vol. 76, no. 2, Apr. 3, 1935, p. MA-19)

APPLIED MECHANICS

Soap-Film Studies

SOAP-FILM analogy for the study of shearing stresses was made use of in the experimental study of effect of size of the fillet on the torsional rigidity of structural beams. About 60 different structural shapes were thus analyzed for torsional rigidity. The experiment brought out the importance of large-size fillets for beams subjected to torsional loads. Further application of the soap-film analogy is at present under way for the study of bending problems and for the determination of the sum of the principal stresses at any point in a section. In the photoelastic experiments the difference in the principal stresses is obtained directly so that the combination of these two methods will fully evaluate each of the principal stresses. (Research at Lehigh University, abstracted through *Engineering News-Record*, vol. 114, no. 17, April 25, 1935, p. 588)

ENGINEERING MATERIALS

Directory of Plastics

THIS is an alphabetical list of plastics commercially produced. It gives the name and address of the manufacturer, the main characteristics of the material, and some of its uses. (*Machine Design*, vol. 7, no. 2, February, 1935, pp. 34–36)

Rapid Nitriding of Steel

RUSSIAN engineers have been greatly interested in the nitriding process but have objected to the long time required for this method of treatment. Work was therefore undertaken in the Research Institute for Aircraft Metals under the direction of Professor Akimov. This work was done on two steels, each containing about 0.25 per cent carbon, 1.50 per cent chromium, 0.40 per cent molybdenum, 0.50 per cent manganese, and 0.50 per cent silicon. In addition one steel had 0.70 per cent aluminum and the other 0.20 per cent vanadium.

About 50 hr at 950 F was required to get a case 0.016 to 0.020 in. thick on these steels and only about 25 per cent of the ammonia was dissociated. If the time was shorter the case was too thin, and if the temperature was raised the depth increased but the case became brittle. Tests embracing various forms of heat treatment are described in the original article. Finally, acting on the assumption that the concentration of nitrogen at the surface and its speed of inward diffusion are roughly proportional to the temperature, a three-stage process was tried. In the first stage the temperature of 930 F was indicated as determining the extent of nitride dispersion. In the

second stage at 1100 or 1200 F a high nitrogen content was built up at the surface and the speed of diffusion inward was accelerated. In the third stage at 930 F the rate of saturation of the outer layers with nitrogen is slower than the rate of diffusion. In this way the concentration gradient and the brittleness at the surface are reduced. Parts are being nitrided commercially by this process in one-half to one-third the time required at 900 F and 65 to 70 per cent of the ammonia is dissociated. (J. E. Kontorovich in *Metal Progress*, vol. 27, no. 2, February, 1935, pp. 43 and 52)

FUELS AND FIRING

Motor Fuels

IN THE laboratories of the Paris Gas Co. an extensive series of tests on binary and ternary fuel mixtures was carried out. A four-cylinder Renault motor with a 75-mm bore and a 120-mm stroke was used. The motor was equipped with means to vary the compression ratio. The first tests were made on a mixture of gasoline and benzol with check tests on gasoline alone. It was found that additions of benzol where the compression ratio was of the order of five clearly increased the motor power, particularly at high speeds. Moreover, the mixture worked well at low speeds, while with gasoline knocking was observed when the speed came below 1500 rpm. At higher speeds, such as 2000, knocking was found at a compression ratio of 5.7 with gasoline and at 6.6 with benzol-gasoline mixture. The alcohol-gasoline mixture was tried next. Tests were made with mixtures containing 10, 15, 20, and 25 per cent alcohol. Notable falling off with power as compared with straight gasoline running was observed at compression ratios of five. On the other hand when the compression ratio was increased the gasoline-alcohol mixtures did better than gasoline alone and knocking was not observed until very high compression ratios were used. It is claimed that when a 10 per cent addition of alcohol was used there were considerable benefits in the way of flexibility, pick-up, and extremely low speed of operation.

It was found that additions of benzol largely corrected the defects of the mixture and the benefits of the addition of benzol showed up even better than when used with pure gasoline. The mixture containing 60 per cent gasoline, 10 per cent alcohol, and 30 per cent benzol gives particularly favorable results from every point of view.

The author compares the results of a 60-10-30 gasoline-alcohol-benzol mixture with 70–30 gasoline-benzol and finds that the addition of 10 per cent of alcohol reduced slightly the power developed at high speeds, but did not produce any notable difference at medium speeds. As far as the knocking is concerned, however, the addition of the 10 per cent of alcohol raised the point in the compression ratio to 6.6. Mixtures of gasoline-benzol with the addition of 15 to 20 per cent alcohol were tried, but did not give especially favorable results, and the conclusion to which the author arrives is that in ternary mixtures the limit of 15 per cent alcohol should not be exceeded if the regulation of carburetion determined for gasoline alone is to be retained. Tests with the standard Renault motor are also described. (J. Verdier in a report of the 13th Congress of Industrial Chemistry, Lille, France, September, 1933, published as a special number of *Chimie et Industrie*, April, 1934, pp. 364–373, 9 figs.)

Vapor Pressure and Heat of Vaporization of Gasolines

THE determination of the various properties of gasolines is a difficult problem because of the complexity of the mixtures which form modern fuels. The present article deals primarily with the vapor pressure and heat of vaporization of gasolines, the author pointing out that it is practically impossible to know the composition of a gasoline; hence the vapor pressure cannot be calculated from the composition, and the simple rule of mixtures does not apply to this case with our present knowledge of the subject. He further states that in the case of a pure body, such as benzine, a curve can be established giving the pressure as a function of temperature, and the same curve holds good no matter how great the volume of vapor may be. On the other hand, in the case of gasolines, the measured pressure at a given temperature depends on the volume available for the formation of the vapor. The larger the volume the lower the pressure. There is nothing surprising about this since the most volatile constituents are the first to evaporate, and as a result the liquid becomes richer and richer in components having a low vapor pressure. In other words we have here in a way an isothermal distillation with the result that in order to study completely a gasoline from the point of view of its vapor pressures, it is necessary to know how the pressure varies as a function of temperature and of the volume of the vapor. This means that in the case of a pure body the vapor pressures are represented by a curve $f(p, t) = 0$, while in the case of a gasoline these pressures are expressed by a surface equation, $f(p, t, R) = 0$, where R is the ratio between the volume of the gaseous phase and the volume of the liquid phase.

The author proceeds to describe his method of measuring vapor pressures which cannot be abstracted because of lack of space. He carried out his tests on both degasified gasolines and natural gasolines, the former having been done on light gasolines of American, Russian, and Rumanian origins, special aviation gasolines, and gasolines used during the War by the German and French air corps. He found that no matter what gasoline was tested, in so far as the ratio R between the volume of the vapor and the volume of the liquid was concerned, the vapor pressures could be deduced from formulas analogous to those used for representing the vapor pressures of pure bodies. He says that the best results are obtained with the d'Antoine formula $\log p = A + B/(c + t)$, where A, B, and c are constants. If instead of pressure the logarithm of the pressure is plotted as the ordinate and as the abscissa $(c + t)$ instead of t, then the curve representing the vapor pressure of a gasoline for a given value of R is a straight line. Knowing the formula giving the vapor pressures, it is easy to calculate the pressure that would exist at a given temperature or the temperature corresponding to a given pressure.

The author succeeded in building up in this way isotherm and isobar curves for each kind of gasoline and gives in the original article these curves for a Russian and a Rumanian gasoline. He also gives the values of the vapor pressure of different gasolines for $R = 6$ in the form of a table, from which it would appear that at —80 C the vapor pressure is practically zero and at 60 C it is about ten times larger than at zero degrees.

From this the author proceeds to the development of a method that would permit characterizing the vapor pressure of gasoline by a single number. He does it by considering the curves of Fig. 1 plotted for the same value of R and representing the vapor pressures of gasolines A, B, C, D, etc. Let T_A, T_B, etc., be the absolute temperatures for which the pressure P is the same for all the gasolines. He next writes down the relations T_A/T_B, T_A/T_C for various values of the pressure P. He finds that these ratios are constant for a given gasoline no matter what the pressure P

may be, and from this it would appear that the curve of vapor tensions for any gasoline can be deduced by multiplying the temperatures relating to the gasoline *A* by a constant factor. A single measurement is therefore sufficient to determine this ratio. Moreover when one considers the ratios T_A/T_B for other values of *R*, it will be found that the same ratio holds good for the same gasoline. From a practical point of view the knowledge of a single vapor pressure

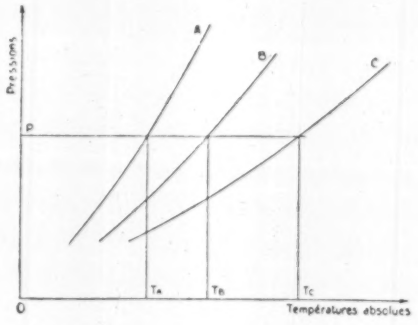


FIG. 1 CURVES OF PRESSURE-TEMPERATURE RELATION OF GASOLINE

permits deducing the value for the gasoline under investigation providing we have the necessary information covering the reference gasoline *A*. From this the author develops the idea of an "index of volatility" and gives some data for its values.

The part dealing with natural gasolines is not abstracted here, neither is the discussion of methods of supplying the gasoline to the motor nor the brief statement as to the heat of vaporization. (M. Schmidt, *La Science Aérienne*, vol. 4, no. 3 (18), May-June, 1935, pp. 168–184, 13 figs.)

INTERNAL-COMBUSTION ENGINEERING

Axial Engine

THIS engine was demonstrated in England and is of the axial wobble-plate type. It has been developed by the Bristol Tramways and Carriage Co. It is said to be very compact; in fact, the reason for its development was to increase the passenger-carrying capacity of a Bristol chassis by decreasing the space occupied by the motor. The principle on which this engine works is that of the swash plate but the plate is a non-rotating member mounted on a Z-shaped shaft as shown in Fig. 2. This member is star-shaped and is connected at the points of the star with the pistons through connecting rods.

The action of the piston rocks the member about its central point. As each piston operates in turn, a rotary motion is transmitted to the Z-shaped shaft which passes through the center of the member.

This construction has certain advantages listed in the original article. Thus the cylinders lie in a compact group instead of being in line along the shaft. The disadvantages are those common to swash-plate design, such as difficulty of balancing and lubrication, which occur when the cumulative stresses due to out-of-balance thrust coincide in certain points of the machine. It is claimed, however, that these forces have been satisfactorily balanced, and while it is admitted that a couple remains in the mechanism tending to twist the webs of the shaft, it is said that owing to the shortness of the shaft and to the freedom which the designer has as to dimensions, these webs can be made big enough to take the load.

The history of development of the engine is next given and a description of the single rotary valve which is used. The valve is water cooled. The principal difficulty here has been to lead the water from the stationary cylinder block to the rotating valve. The joint to do it has been contrived by means of two "packless" joint rings of different diameters. The water passage is the annulus formed between them. This method has proved perfectly satisfactory. No attempt has been made to adopt any directional flow for the cooling water to the valve. Some difficulty was experienced in maintaining the same temperature for all cylinders,

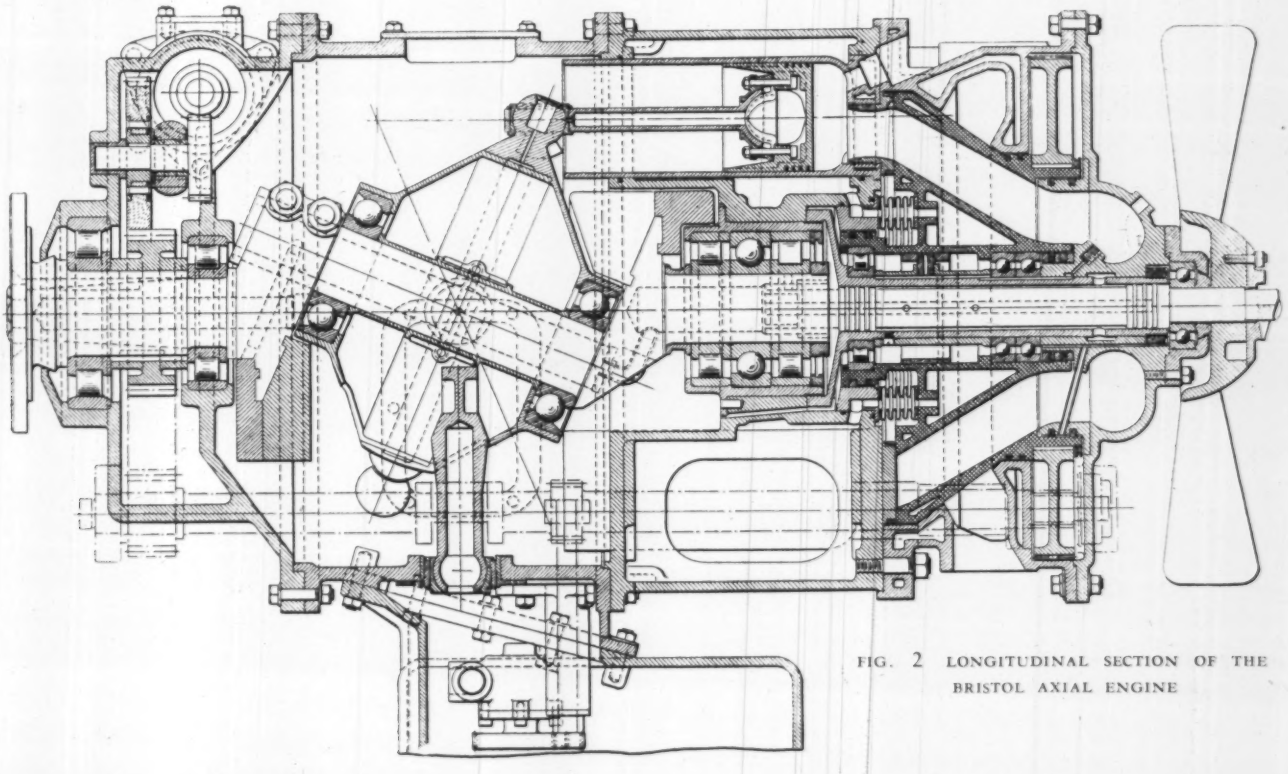


FIG. 2 LONGITUDINAL SECTION OF THE BRISTOL AXIAL ENGINE

but was overcome by admitting the cold water at the top of the engine and removing the hot water at the bottom.

Lubrication of the engine proved simple. Dry-sump forced lubrication is provided for the Z-shaft bearings and the star member bearings. Sufficient oil for the connecting-rod joints and pistons is provided by a small jet set at the bottom edge of the cylinder. It is said that the Bristol Company declares the new engine to be superior to their own J W six-cylinder omnibus engine. The low friction in the new engine was shown by the fact that in motoring the two engines on the test bed, 10 amperes sufficed for the new engine against 40 amperes for the J W. It weighs less than the J W engine and it is believed will be cheaper to manufacture. (*The Engineer*, vol. 159, no. 4141, May 24, 1935, pp. 545–547, 11 figs.)

MACHINE DESIGN

Voith Turbo Transmissions

THE attainable efficiency depends in the first place on the blading. The optimum efficiency in the impeller turbine and guide wheels is theoretically attainable. The modern theory of flow and studies of the flow through turbine wheels, made in the design of turbines and pumps, have had a decisive influence on the shape of the blades. The effect of this influence must be considered over the whole blade shape, and especially for the conditions at the inlet and outlet of the blade. The optimum efficiency in the impeller turbine and guide wheels (for non-adjustable blade angles) is theoretically attainable only at a single point of the efficiency curve. The efficiency curve can, however, be kept sufficiently flat and satisfactorily high for all the wheels over a reasonably large range of speed by means of a suitable shape for the rotating and stationary blading. It is known that in turbines and pumps, for instance, more favorable efficiency curves can be obtained by making the runner-blade angle adjustable (as in Kaplan turbines and pumps) and by corresponding adjustment of the angle of the guide vanes. This holds true also with turbo transmissions, but on account of their small dimensions, a complicated design is involved if the blades are made adjustable, and this cannot be justified by consideration of the possible gain in efficiency on one hand and of the decreased reliability on the other. In particular, the vibrations which occur with these movable blades under certain conditions reduce the reliability. Actual service tests on the reliability of adjustable-vane constructions, however, have not yet been sufficient to give decisive results. The Vickers-Coats type of torque converter offers an example, with pivoted vanes in the guide wheel arranged to adjust themselves automatically to the change in direction of the flow.

In the application of torque converters to rail cars, the zones of low efficiency only predominate at the start and for a relatively short time. Hence it is obvious that the advantage of reliability is essentially greater than the relatively small gain in efficiency obtainable by adjustable vanes over this range.

To sum up, it may be repeated that the secondary torque of a converter is determined, apart from the choice of the blading, by the quantity of circulating liquid and the pump pressure. In order to obtain a certain secondary torque characteristic it is not absolutely necessary for a turbine wheel to have two or more stages. A high starting torque can be reached with a single-stage turbine wheel. The character of the curve of primary torque at constant motor speed is chiefly influenced by the manner of inflow to the impeller. The primary torque remains constant, or nearly constant, if a guide wheel is arranged directly before the primary impeller. The primary torque curve changes at constant motor speed if the liquid flows from the turbine (or secondary) runner directly into the primary impeller.

The details of the device and some of its installations are given in the original article. Curves in the original article would indicate that of the mechanical speed-change gear, the Voith gear, and electric transmission, the mechanical gear alone gives the higher tractive effort at certain points, while at other points this gear is surpassed by the Voith transmission, which, in addition, is entirely free from difficulties of effecting shockless gear changing. Reference is made to a new hydraulic transmission for a 150-hp Austro-Daimler Diesel motor built with a speed-increasing gear installed on the primary side in order to reduce the dimensions of the transmission. Also the 1380-hp Diesel hydraulic locomotive has been constructed with a Voith turbo transmission of the duplex type having two couplings on the coupling side. The two couplings drive through gears of different ratio on the secondary side, so that a still more favorable approach of the tractive effort toward the ideal traction curve is possible. (Paper by Dr. of Engrg. Wilhelm Hahn, read before the Institution of Mechanical Engineers, May 3, 1935, abstracted through *Engineering*, vol. 139, no. 3617, May 10, 1935, pp. 489–490, and *The Engineer*, vol. 159, no. 4139, May 10, 1935, pp. 494–495)

MACHINE PARTS

Tests on Behavior of Riveted Joints of Steel Structures Under Alternate Bending Moments

THE object of these tests was to determine the behavior of riveted joints connecting the columns and girders of steel structures under alternate bending moments. The excellent earthquake-proof quality of steel structures was demonstrated in the great disaster that befell the Kwanto districts in 1923. But this earthquake-proof quality of steel structures has never been investigated either theoretically or experimentally. The present investigations were carried out in order to ascertain both experimentally and theoretically what these characteristics are.

The ductility of riveted joints is remarkably great, and in these tests no part of the joint was pulled out or crushed, though a load some three times as large as the working load was applied to each test piece to bring about great angular strain.

In these overloaded test pieces no visible deformation remained after smaller load cycles were applied, as would happen in the case of an earthquake.

This characteristic is noteworthy as being one of the superior earthquake-proof qualities of steel structures. Under loads higher than the working loads the rigidity of joints decreases remarkably, but the load-deformation cycles take in a remarkable area and the consumption of energy shown by this enveloped area of the hysteresis loop acts as a vibration-damping source upon the structure. Thus the overbending of structural-steel joints under earthquake influence is not in itself dangerous to the stability of the structure, and no effect of resonance is to be feared on the stability of the structure, as the upper limit of the deformation caused by the resonance lies in the elastic limit of the deformation of the structure, this being quite harmless from the point of view of the safety of the structures.

Though the enveloped area of load deformation cycles decreases under the second action of the load, the vibration-damping quality is not lost. Moreover if another larger shock follows and acts upon the structure, then a large energy

consumption is accomplished by the overbending of joints and the amplitude of the vibration decreases rapidly. This is one of the most recommendable earthquake-proof qualities of steel structures that the author can conceive. (Rio Tanabashi in Memoirs of the College of Engineering, Kyoto Imperial University, vol. 8, no. 4, March, 1935, pp. 164–175, 31 figs.)

Impact and Static Tensile Properties of Bolts

IMPACT and static tensile tests were made on bolts with nuts having American National coarse threads, American National fine threads, and Dardelet threads. The nominal diameters of the bolts were 3/8, 1/2, 5/8, and 3/4 in. The materials were heat-treated chromium-nickel steel, cold-rolled steel (Bessemer screw stock), monel metal, bronze (copper-silicon-manganese alloy), and brass. The length of each bolt from the head to the bearing face of the nut was five times the nominal diameter. The exposed threads on the bolt extended from the bearing face of the nut toward the head for one diameter. Four similar specimens of each material, diameter, and thread were tested under single-blow impact loading and two under static loading. The total number of specimens was 360. The following conclusions were drawn from the results of the tests:

(1) In the impact tests two chromium-nickel bolts with American National fine threads failed by stripping the thread. More than one-fourth of the cold-rolled steel bolts with American National threads, both coarse and fine, had "brittle" failures. These anomalous failures gave erratic and low impact values. Otherwise similar bolts having Dardelet threads gave no such erratic results.

(2) Except for the brass bolts and those which showed stripped threads or brittle failures, the work per unit volume required to rupture the bolts either under impact loading or under static loading was for each material and for each type of thread approximately independent of the diameter of the bolts. There was, however, an indication that the work per unit volume was dependent somewhat upon the ratio of minor to major diameter of the thread.

(3) Except for the brass bolts and those which showed stripped threads or brittle failures, the stretch in the one diameter of exposed threads either under impact loading or under static loading was for each material and each type of thread approximately independent of the diameter of the bolts.

(4) In all cases the impact works for bolts having American National coarse threads were less than the impact works for bolts of the same size and material having American National fine threads.

(5) Except for the brass bolts and those which showed stripped threads or brittle failures, the impact works for bolts having American National fine threads were approximately the same as the impact works for bolts of the same size and material having Dardelet threads. The impact works for brass bolts having American National fine threads were on the average 12 per cent less than the impact works for brass bolts having Dardelet threads.

(6) In all cases the impact works for bolts having Dardelet threads were much greater than the impact works for bolts of the same size and material having American National coarse threads.

(7) In all cases the static works for bolts having American National coarse threads were less than the static works for bolts of the same size and material having American National fine threads.

(8) Except for the brass bolts and those which showed stripped threads or brittle failures, the static works for bolts having American National fine threads were approximately the same as the static works for bolts of the same size and material having Dardelet threads. For the brass bolts the static works for bolts having American National fine threads were on the average approximately 26 per cent lower than the static works for bolts of the same size having Dardelet threads.

(9) In all cases the static works for bolts having Dardelet threads were greater than the static works for bolts of the same size and material having American National coarse threads.

(10) In all cases the maximum static loads for bolts having American National coarse threads were less than the maximum static loads for bolts of the same size and material having American National fine threads.

(11) In all cases the maximum static loads for bolts having American National fine threads were approximately the same as the maximum static loads for bolts of the same size and material having Dardelet threads.

(12) In all cases the maximum static loads for bolts having Dardelet threads were greater than the maximum static loads for bolts of the same size and material having American National coarse threads.

(13) For bolts of the same size and having the same threads the static-bolt efficiencies, defined as the ratio of the maximum static load for the bolt to the load computed by multiplying the cross-sectional area of the shank by the ultimate tensile strength of the material, were approximately the same for all of the materials. (Herbert L. Whittemore, Geo. W. Nusbaum, and Edgar O. Seaquist, Research Paper RP 763, Part of *Journal of Research* of the National Bureau of Standards, vol. 14, February, 1935, pp. 139–188, 23 figs.)

MACHINE-SHOP PRACTICE

Local Surface Hardening of Crankshafts

THIS new method differs from either case-carburizing or nitriding, and consists in locally heating, for example by means of an oxyacetylene torch, the desired spot on the shaft and then quenching it. One of the particular advantages of the process is that instead of taking hours and days as do case-carburizing and nitriding, it can be performed in a few minutes. Its field of application hitherto has been limited but new possibilities are being uncovered. It may be used, for example, for hardening teeth in gears exposed to harsh side wear.

In many cases, particularly in Diesel engines, it is desirable to increase the hardness of the journals in the bearings so as to improve the wearing resistance. It is claimed that over 200,000 shafts hardened by this process are in operation and giving excellent satisfaction.

These shafts have to be made of heat-treatable steel and the hardening treatment produces in the places where it is applied a very hard layer several millimeters thick and enclosing the core as by a jacket. The process of hardening is effected as follows: A suitable burner heats locally the part of the journal while the shaft is being rotated. A special device is used to produce quenching. The heating of the shaft is controlled by optical pyrometers, while the duration of the heating is checked by a stopwatch. After the crankshaft has been hardened it is submitted to several hours of annealing at 180 to 200 C. This is done partly in order to neutralize the stresses set up during the heating and partly to improve the properties of the material of the shaft.

It is important that a proper alloy should be used for the shaft. The nature of the process is such that no foreign material is introduced and therefore the steel must be so alloyed that after being locally heated beyond the Ac_3 transformation point and being quenched it should

have an increased hardness on the spots treated.

Another condition which must be satisfied is that the supply of heat to the surface of the material should be more rapid than the conduction of heat to the core of the piece. It is only in this way that a substantial accumulation of heat at the place to be hardened can be produced. In other words, the process of local surface hardening may be said to consist in producing a local rise of temperature in such a manner as to exceed the upper transformation point of the steel. The quenching immediately following the heating must then produce the hardening if the steel is of proper composition. It was necessary to determine experimentally what velocity of heating would satisfy these requirements.

The remainder of the article gives an analysis of metallurgical phenomena occurring in the steel and practical instructions for the carrying on of the process. Chrome-molybdenum steels satisfy the requirements of this process. (Dr. of Engrg. H. Voss in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 24, June 15, 1935, pp. 743–749, 21 figs.)

METALLURGY

Porosity in Steel Castings

THIS is from a symposium presented before the American Foundrymen's Association.

In his paper on the preparation of steel to avoid porosity in castings C. E. Sims gives three main sources for porosity: Condition of the metal, condition of the mold material, and construction of the mold. The paper is concerned with the preparation of the metal. Gases which occur in steel are stated to be carbon monoxide and carbon dioxide, present only as reaction products, and hydrogen and nitrogen, which are soluble as hydride and nitride, respectively. The author explains the rôle played by equilibria and surface tension. He states that the porosity problem resolves itself into (1) reducing dissolved gases as much as possible, and (2) producing the conditions most favorable for retaining in solid solution those gases that could not be eliminated. Conditions favoring the first step, or low gas content, are a long, vigorous boil, thorough oxidation, low residual silicon and manganese, moderate temperature, late oxidation, and no increase in temperature after deoxidation. Conditions favoring retention of gases in solid solution are thorough deoxidation and minimum exposure after deoxidation. The author states that control through selection of charge and control of atmosphere seems both impractical and unnecessary.

In discussing the effect of the mold and cores on porosity in steel castings, George Batty, points out that the sand from which molds are made influences that defect considerably. In sands made from silica sand and bonding materials, he shows that the characteristics of both the sand and the bonding materials influence the solidity of the casting. He outlines the properties of sands for green, skin-dried, and dry-sand molding, and points out that the expansion of the interspacial atmosphere and the gases given off by the binders are two causes of porosity. He also states that the prevention of porosity in steel castings is an individual foundry problem. He discusses the properties of binders and explains the effects of various constituents of molding sands in various types of molding. He stresses the importance of the permeability of backing sands and explains why such sands should be higher in permeability than the facing sands. The functions of a good sand-reclaiming system are discussed as is the question of new versus reclaimed sand for facings. The effect of various systems of molding on porosity and the effect of flask and jacket equipment are discussed in relation to the promotion of porosity. The author urges the use of specially prepared gate cores as a remedy for certain types of porosity and explains how they are made and how molding procedure can be changed to make use of them. He blames some types of porosity on improper gating and gating materials. The latter portion of the paper is devoted to a discussion of the effects that cores and materials used in their manufacture have in the promotion of porosity.

R. C. Woodward's paper on the mechanics of porosity in steel castings deals with that type of porosity which is seen just under the surface of castings, often called "pinhole" porosity. A study of rejection records of a certain steel foundry over a period of six years, included 21,057 castings. By microscopic examination, a relation was found between the non-metallic inclusions on the surface near the pinholes, and the amount of porosity. It was also found that porosity was greater in the summer. A theory which explained these facts is given.

In the paper on the function of the steel-foundry foreman in preventing porosity R. A. Bull, confining his discussion mainly to practical rather than to purely scientific phases of the pinhole problem, first devotes attention to conditions incidental to contaminating possibilities in metal transfer from furnace to mold. Then comments are made regarding the influence of aluminum in forming inclusions. Following this there are listed possible causes for porosity which are generally controllable to some extent by the men responsible for making molds and cores, and pouring the steel. Finally, comments are made regarding the inter-relationship of possible causes for porosity, and the delicate balance necessary to prevent this defect. (Transactions American Foundrymen's Association, vol. 6, no. 2, April, 1935, pp. 323–406)

MOTOR-CAR ENGINEERING

Diesel-Driven Heavy Trucks in Germany

OFFICIAL statistics regarding the use of Diesel engines in trucks, buses, and tractors in Germany are available for the first time for the last half of 1934. Compared with 10,098 trucks and delivery wagons equipped with gasoline engines, 3827 registered were equipped with Diesel and 78 with other engines. However, more than half of the trucks with gasoline engines were vehicles of less than one-ton capacity. In the heavier classes the Diesel is much more strongly represented. Thus 89 per cent of all trucks between 3 and 4 tons, 87.1 per cent of all between 4 and 5 tons, and 92.3 per cent of all over 5 tons were Diesel equipped. Of the motor buses registered during the six-month period, 180 were powered with gasoline and 250 with Diesel engines, while one had a power-plant of a different type.

Of the bolster-type tractors 58 carried gasoline engines, and 143 Diesel engines, while of the drawbar tractors 120 had gasoline engines, 744 hot-bulb engines, and 943 Diesel engines. Here too the proportion of Diesel-engined machines is greatest in the larger-size classes. (*Automotive Industries*, vol. 72, no. 22, June 1, 1935, p. 736)

NATIONAL DEFENSE

Future of Air Warfare

THE author considers the aims to be pursued by an air force, meaning by the latter an independent unit and not a mere auxiliary of the Army or Navy. A modern air force will consist chiefly of bombing machines which will proceed against a series of carefully selected air objectives, the destruction of which would seriously hamper the conduct of the war. An enemy air force attacking

the United States, for example, would proceed immediately to destroy the two factories on which the U. S. Army and Navy are at present solely dependent for aviation engines—that of Pratt & Whitney at Hartford, Conn., and that of Wright at Paterson, N. J. Destruction of these two factories, easily accessible to bombing aircraft from an Atlantic fleet or from Canadian bases, would seriously hamper the further production of engines, if it did not stop it entirely for some time and thus render it impossible to replace our own losses of aircraft before the enemy had won a victory. Aerial bombardment of munitions plants, most of which are on the Atlantic seaboard, would be inevitable, as would the bombardment of Navy yards and shipbuilding plants, so that we would be hampered not only in the production of new ships, but also in the repair of those damaged in sea battles. (By Caldwell, *Aero Digest*, vol. 26, no. 3, March, 1935, pp. 16, 17, and 70, 2 figs.)

POWER-PLANT ENGINEERING

Removal of Sulphur From Chimney Gases

THE article deals primarily with the Howden-I.C.I. process of combustion-gas treatment already installed in several important stations in England. The basic principle consists in scrubbing the entire volume of the combustion gases with lime or chalk sludge using a new design of compact "lath" type of scrubber operating under such conditions that no effluent is formed. The sludge is constantly recirculated and the resulting calcium sulphide and sulphate formed are separated by gravity and by means of mechanical filtration producing relatively hard cakes. The liquor is returned to the circuit to which fresh lime or chalk-sludge make-up is added continuously. It is claimed that about 95 per cent of the dust and sulphur compounds is removed.

In this connection attention is called to a publication issued in December, 1934, by the Minister of Transport and Agriculture and entitled, "Treatment of Chimney Gases at the New battersea Power Station of the London Power Co., Ltd." (Cmd. 4771, dated Oct. 15, 1934.) The Battersea process has been successful but is not described here as it is already well known. Several American papers are also cited by the author. The author says that in his opinion the whole principle of treatment of the vast column of combustion gases is on wrong lines. A much more economical and scientific proposition would seem to be to remove the sulphur before combustion combined with electrostatic methods for the dust. This could be carried out by one of two processes, that is, combined low-temperature carbonization and combustion both of the solid fuel and of the purified gas, or by combined low-temperature carbonization and total gasification with combustion of the gas after purification. (David Brownlie, article based on a paper entitled, "Removal of Smoke and Acid Constituents From Flue Gases by a Non-Effluent Water Process." *The Steam Engineer*, vol. 4, no. 8, May, 1935, pp. 331–333)

RAILROAD ENGINEERING

Superspeed Railroad Trains

THE article deals with some of the basic features that made the design and construction of modern superspeed trains possible. It points out that in 1921 Henry Ford was quoted as saying that engines and cars are four or five times as heavy as they should be. It should be remembered in this connection, however, that many of the designs of today would have been impossible even five years ago. It has been only since 1930 that the Aluminum Company of America, after much research and experimenting, began to produce commercially the large plates and extruded sections required in car building. Spot-welding of stainless steel is less than five years old, while the low-alloy, high-strength steels have come into commercial use only within the last two years. Other recent developments include the improvement in fusion welding, new high-strength alloy steels, improved foundry practice and metallurgy resulting in bigger and better steel castings, new types of rubber, and high-capacity roller bearings.

In the design of aluminum cars, such as those built by the Pullman Company, the use of extruded sections made possible numerous design innovations. As an example, one of the extruded aluminum sections in the built-up central longitudinal roof member is not only a load-carrying member, but is also the gutter in which the lamps for the indirect lighting are mounted.

Because the size of the cross-section of extruded aluminum members is at the present time limited to about 12 in. across the maximum distance, larger members must be built up with two or more sections. To join these sections longitudinally the Pullman Company developed a design wherein a tongue or bead on one section fits snugly into a mating groove in the other section; the tongue and groove extending the full length of the members. Bolts or their equivalent hold the members together. It is claimed that with the extruded section built-up as described the assembled member acts as a single unit.

Of the individual features of design attention may be called to the following: In the aluminum streamlined unit train, the Comet, the car is constructed as a tube with flat sides and arched roof and bottom, whereas standard railroad cars use either the center sill or truss-type underframe. In the Comet the shell consists of a framework covered on the outside with heavy formed sheets, all of aluminum. Placing the heavy sheets in the circumference of the shell makes the most effective use of the metal for resisting bending and torsion. In the Baltimore and Ohio train a floating center sill is used. The car body is attached to the Duryea floating center sill by means of helical springs and connecting rods which permit the total travel of the body on the center sill of 4 in. forward and backward. The buffing movement is resisted by rubber pads.

One of the Baltimore and Ohio trains is built of Cor-ten steel, the weight of the train being about 60 per cent that of comparable existing conventional steel equipment. The other train, except for the center sill, is built of aluminum alloy, and weighs about 53 per cent of that of a comparable train of conventional construction. One of these trains will be pulled by a steam locomotive and the other by the new Winton 3600-hp Diesel-electric locomotive.

In the trains of the Gulf, Mobile, and Northern Railroad no rivet heads appear on the outside, the outside sheets being secured to braced channel-shaped posts by spot welding.

One far-reaching development that has not received much publicity has been in steel castings. According to John E. Muhlfeld, consulting engineer, the substitution of integral cast-steel locomotive beds, which include the cylinders, valve chests, frames, cross ties, decks, foot plates, and the air and other reservoirs, will reduce the number of parts at least 900 pieces as compared to fabricated assemblies.

Since the ruling of the American Railway Association that after January, 1936, there shall be no more arch bar trucks in use, there has been a tremendous incentive toward the improvement of steel castings for truck side frames. One of the requirements for cast-steel side frames includes thin sections to procure light weight. At the same time, one of the difficulties in such castings was shrink-

age and quenching cracks. This required an alloy steel with exceptional fluidity so that it would not freeze in the mold, and also preferably one that would not require heat treatments involving liquid quenching and tempering. That is, it required a steel with the desired physical properties when in the normalized condition, which also has the advantage of producing a product of dependable uniformity.

Researches and tests conducted in the foundries of the Pressed Steel Car Company developed a cast nickel steel with minimum physical properties of 90,000 lb per sq in. tensile strength, 60,000 yield point, with a reduction of area of 40 per cent, and an elongation in two inches of 25 per cent. As compared to carbon-steel castings, having an ultimate tensile strength in the range of 70,000 lb per sq in., this new steel, Prescoloy, enabled the design of side truck frames with a reduction in weight of approximately 16 per cent. Bolsters cast of the same material showed a saving of 20 per cent in the weight, all of these savings being primarily by virtue of the fact that not only was the steel of higher physical property, but also enabled the casting of thinner sections.

Another aim in the development of steel castings for railroad service is to obtain a high ratio of yield point to ultimate strength. This is to assure a high fatigue resistance. It is pointed out by John E. Muhlfeld that great care must be exercised in changing from carbon steel to alloy steel. In explaining the failure of alloy-steel axles of similar design as carbon-steel axles which did not fail in service, Mr. Muhlfeld points out that the higher ductility of the carbon steel results in lower stress concention. (*Product Engineering*, vol. 6, no. 6, June, 1935, pp. 202–208, illustrated)

Electrical Power Transmission in Diesel-Driven Motor Coaches

THE author compares the electrical method of power transmission with the mechanical. In a general way, he says, the question of the best method of power transmission for low-power Diesel vehicles, that is, up to about 300 hp, is even more a matter of controversy today than before. The decision should rest on a number of other factors besides the power of the Diesel engine. The principal arguments brought forward against electric power transmission are heavy weight and high purchase cost. However, it has recently been found, possible to reduce considerably the weight of the electrical equipment. On the other hand, mechanical power transmissions increase in weight with the increase in the demands of length of life and upkeep. The difference in weight of the transmission proper does not exceed 30 per cent today. As the portion of the total weight of the coach in running order which belongs to the power transmission is only about 15 to 20 per cent, the extra weight due to using electrical power transmission can only increase the weight of the coach by about 6 per cent at the most. The same considerations are valid for the purchase cost. Further, the higher cost of purchase is more than compensated for by the lower outlay for renewal and upkeep.

Argument against electrical power transmission is its lower efficiency, 82 per cent maximum on main-line stations as compared with 90 per cent with mechanical transmission. This does not mean, however, that with electrical transmission a more powerful Diesel engine is required with correspondingly higher fuel consumption. The influence of the lower efficiency is compensated for by the fact that full use of Diesel-engine power can be made continuously with electric power transmission. Thus the starting acceleration is superior to that of the coaches with mechanical power transmission. Moreover, with electrical power transmission it is possible to run the Diesel engine at all times at that speed which corresponds to the most economical fuel consumption. The author comes to the conclusion that even for low Diesel-engine outputs electrical transmission may have its advantages, particularly under certain operating conditions. The arguments, pro and con, covering the two forms of power transmission, are presented in the original article in addition to the general discussion in parallel statements. (Dr. E. Meyer, *The Brown Boveri Review*, vol. 22, no. 6, June, 1935, pp. 122–127, 6 figs.)

SPECIAL MACHINERY

Solid-Frame Forging Press

IN this press placed on the market by the Ajax Manufacturing Co., of Cleveland, Ohio, the frame is a solid one-piece steel casting of heavy cross-section to provide rigidity. It also provides least stretch through members of equal cross-sectional area and eliminates the uncertainty of tie rods due to variations in the preloaded and peening-down of the bearing surfaces of tie-rod nuts, as well as the disadvantage of additional material in tension through the full tie-rod length, all of which transfer an increasing proportion of the load to the frame proper. This rigidity between main bearings and die seat not only improves the uniformity of the work produced, but increases the die life through shortening the time the dies are in contact with the metal by the period which would ordinarily go into stretching the frame and deflecting and compressing the working parts.

The ram derives improved alignment from a top extension bearing at the rear side of the crown rib of the frame, thus securing unusual guide length without increased length of frame in tension or length of pitman and slide in compression. These presses are air-clutch controlled by a direct, pneumatically operated, multiple-disk friction clutch. This type of clutch is claimed to be very fast in operating. (W. C. Kernahan in *Heat Treating and Forging*, vol. 21, no. 4, April, 1935, pp. 179–181, 5 figs.)

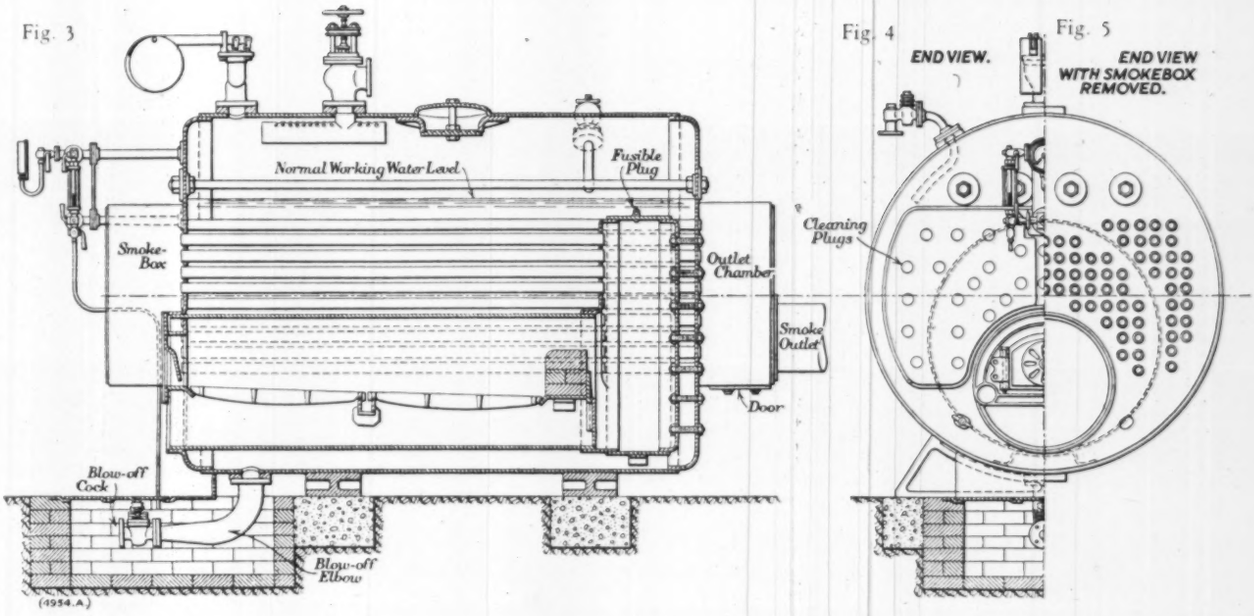
STEAM ENGINEERING

Horizontal Thermax Boiler

THE vertical boiler of this type manufactured by Ruston and Hornsby, Ltd., of Lincoln, England, is well known. This horizontal boiler was first shown at the British Industries Fair at Birmingham now under way.

The essential features of the new boiler are a wet-back combustion chamber and two sets of fire tubes. The wet-back combustion chamber is naturally more efficient than the brick-lined chamber necessary on the standard type of dry-back boiler, as in the case of the latter there is a certain amount of radiation to the surrounding atmosphere, while in the new boiler all the heat which is taken from the gases at the combustion chamber is transferred to the water.

The products of combustion pass through the boiler flue to the combustion chamber, thence through a bank of tubes to the smokebox at the front, returning to a chamber at the rear of the boiler through another set of tubes. The arrangement of the tubes will be clear from Figs. 3 and 5, and it will be seen that the second set of tubes is divided into two nests, arranged on either side of the wet-back combustion chamber, and at the same level as the first set of tubes. This arrangement, in the main, avoids taking the final pass where the gases are at their coolest through the top part of the boiler, where the water is at its highest temperature. The rear end chamber is connected to a chimney. A small but important feature of the design is the pro-



FIGS. 3 TO 5 HORIZONTAL THERMAX BOILER

vision of a number of tube-cleaning holes in the smokebox, as shown in Fig. 4, one cleaning hole being provided for every four tubes. Through these the tubes can be cleaned while the boiler is under steam, thus saving a considerable amount of time in the morning, as the usual procedure is to open the smokebox doors and clean the tubes before starting up. With previous designs, the fireman in many cases simply cleans the tubes when he has time, with the result that the tube surfaces are allowed to become dirty and the efficiency of the boiler is reduced. With these patented cleaning doors there is no reason why the tubes should not be maintained free from soot and the boiler efficiency maintained. The horizontal Thermax boiler is offered in sizes from 1000 lb per hr evaporation upward. Its overall dimensions are considerably less than those of other types of horizontal boiler. Moreover, it is entirely self-contained and no brick setting is therefore required. Automatic stokers can be fitted for burning low-grade coal and the boiler can be equipped with any recognized make of oil burner. (*Engineering*, vol. 193, no. 3618, May 17, 1935, pp. 507)

High-Pressure Boiler With Fusion-Welded Drums

THIS boiler, recently installed in England, consists of a single bank of inclined tubes which forms the connection between the upper and lower drums.

The feedwater enters the main steam and water drum near its end so that the downtake tubes, which are closely adjacent, are supplied directly. These tubes which provide a positive feed to the bottom drum are not exposed to the gases but are built into the side walls. All the tubes which form the actual heating surface are thus free to act as steam risers.

The first line, however, consists of half a row only and forms a slag screen. Both this and the next row are exposed to radiant heat and discharge above the water level into a baffle trough with openings at the end. The large volume of steam generated in these tubes has therefore time to separate from the entrained water, and further separation is effected by passing the steam into the receiver drum located above the steam and water drums. The heating surface of the boiler is 2750 sq ft, the maximum evaporative rate 7.3 lb per sq ft per hr, the working pressure 415 lb per sq in., and the combustion-chamber volume 1120 cu ft.

In regard to the welding process it may be mentioned that both the longitudinal and circumferential joints are of the double-welded butt type. The weld metal was deposited in layers, and particular care was taken that no valley or groove was left along the edges or in the center, and that no bending stresses were brought on the joint.

As there are no British rules for this type of welded construction, the manufacture was carried out in accordance with the regulations of The American Society of Mechanical Engineers' Boiler Code. The efficiency of the joint was taken as 90 per cent, and both destructive and non-destructive tests were made. The former comprised tension tests on the joint and the weld metal and a bend test transverse to the joint, while the latter consisted of a radiographic examination of all the longitudinal and circumferential joints.

After the completion of the welding, the drums were stress-relieved by slowly heating them to a temperature of at least 1100 F and keeping them at that temperature for a time based on at least one hour per inch of thickness. They were then allowed to cool slowly in a still atmosphere. All the connections, which are attached by fusion welding, were also treated in the same way. The drums were further subjected to a hydraulic-pressure test of 900 lb per sq in., during which they were vigorously hammered. The top drum has an internal diameter of 45 in. and is 15 ft long, the thickness of the metal being $1\frac{1}{2}$ in. The bottom drum is 13 ft $7\frac{1}{2}$ in. long and $39\frac{3}{8}$ in. internal diameter, the thickness being $1\frac{5}{16}$ in., while the receiver is 8 ft 3 in. long, 24 in. in diameter and $\frac{11}{16}$ in. thick.

The boiler is said to have been in regular service since the beginning of 1934, the average output being 14,000 lb and 8000 lb of steam per hr during the day and at night, respectively. (*Engineering*, vol. 139, no. 3619, May 24, 1935, pp. 554-555, illustrated)

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Henry Laurence Gantt

HENRY LAURENCE GANTT: LEADER IN INDUSTRY. By L. P. Alford. Harper & Brothers, for The American Society of Mechanical Engineers, New York, 1934. Cloth, 6 × 8¾ in., 315 pp., frontispiece portrait and other illustrations, $5. ($4 to members of A.S.M.E.)

REVIEWED BY W. L. BATT[1]

PROMINENT among the directive forces and influences that mold character and prepare for a life of work are a man's home and parents, his schools and teachers, and his implanted ideals and honored heroes."

With these words L. P. Alford opens his review of Henry Laurence Gantt's life and work.

The name of Gantt is so intimately associated with scientific management that one might expect this biography to be essentially a history of that movement, a volume wherein the life of the man became secondary to the work with which he was so significantly associated. This reviewer was pleasantly disappointed, for here is vividly pictured the life of a man—a man of extraordinary imagination and large heart, who saw the working man in a new and vital relationship to his work and sought for means to encourage and reward him as a fundamental factor in intelligent industry.

Those who knew Gantt intimately describe him as a very human person—a person with an abundant vision of the other fellow's difficulties—patient to a fault, but one who could on occasion display an inexorable firmness when he was convinced he was right. It is such essential and vital qualities in Gantt that this author has seized upon and expanded in a most interesting fashion.

Of course this biography includes the usual historical data, but particular emphasis is laid on Gantt's early life, on the marked influence of his parents and particularly the hardening and refining effects of his boyhood days when the family faced want and privation. Even as a boy really extraordinary qualities of mind and heart are seen to appear in young Gantt. His boyhood hero was "Stonewall Jackson" and the qualities of fearlessness, quick decision, and lack of self-interest that were so essentially Jackson's became Gantt's ideals.

As Gantt came into the fullness of mental stature, the rapid expansion of industry was encountering a wide range of problems in which the human element had taken on a new significance. Into this arena Gantt threw himself with heart and soul and his remarkable contributions are matters of common history.

One does not have to be a student of scientific management to enjoy this book. Its pages are filled with a philosophy of industry which bears in direct terms on the very problems which industry is facing today. One feels that Gantt would have thrilled to the challenges of the New Deal and NRA.

[1] President, SKF Industries, Inc., Philadelphia, Pa. Vice-President, A.S.M.E.

The New Physics

ELECTRONS (+ and −), PROTONS, PHOTONS, NEUTRONS, AND COSMIC RAYS. By Robert Andrews Millikan. The University of Chicago Press, 1935. Cloth, 5 × 7¼ in., 492 pp., 98 figs., $3.50.

REVIEWED BY E. R. HEDRICK[2]

WHY should the public, why should the members of the A.S.M.E., take an interest in the abstruse physical and mathematical investigations of the nature of the atom, of electrons, and of the intricate composition of the heavier atoms? Though there is a tendency to point out possible results in practical physics and in engineering, as Millikan does in the preface to this book, I doubt whether the public, certainly the readers of this journal, need the stimulus of the possibility of gainful application to arouse their interest. All intelligent people have shown absorbing interest in the nature of the universe and in the nature of matter from the very dawn of history. I do not doubt that great applications will follow the recent discoveries, but it is not the thought of gain that holds public interest in the nature of the atom, any more than it is for that larger cosmos of the distant star-nebulae, the island universes, of which no application is reasonably thinkable.

I shall not, then, make any apology, nor do I claim any particular practical application, when I assert that every reader of this journal will find this book welcome and stimulating. I speak particularly of those who read this journal, since they will not be frightened, as the general public might be, by the few mathematical formulas, nor by the physical terms and concepts. Waldemar Kaempffert, in a review of it in the New York *Times*, Jan. 27, 1935, says that the public "will vote the popularizations of Jeans, Eddington, and Russell easier reading than this book of Professor Millikan's;" but I do not believe that this statement would hold true for the great majority of engineers. After all, the mathematics in it is incomparably simpler than is the mathematics of many articles in this journal. True, the work of many investigators in this whole field (Bohr, Sommerfeld, de Broglie, Schrödinger, Heisenberg, Dirac, and many others) is highly mathematical; but Millikan's own work has been primarily experimental, and he has specifically attempted to present here the results of experiment, as well as the theory, from a non-mathematical standpoint.

The entire work is more than an explanation of the present state of knowledge. It is very definitely an account, going back to the earlier days of modern physics, even to the days of the ancient Greeks, of the growth of conceptions regarding matter, atoms, and electricity. It recounts the successive stages by which the present knowledge has been gained. Thus the first chapters recall briefly the conceptions of the Greeks, and then more specifically the experimental and theoretical investigations of the nature of electricity in the middle of the nineteenth century by such men as Faraday, Hertz, Maxwell, Weber, Lord Kelvin, Helmholtz, and others. It is shown that the laws of electrolysis in particular led to definite ideas of the existence of a unitary electric charge, and to efforts toward the determination of the absolute value of e, the primary unit of electric

[2] Professor of Mathematics, University of California at Los Angeles, Los Angeles, Calif. Mem. A.S.M.E.

charge. The word "electron" itself goes back to Dr. G. J. Stoney, who suggested it in 1891 as a name for the "natural unit of electricity."

Passing over the earlier efforts to measure e, made by such men as Townsend, J. J. Thomson, Wilson, Wien, and others, which are now mainly of historical interest, Millikan explains very properly, and with intimate disclosure of his difficulties and discouragements, his own noted oil-droplet experiments, which began in 1909 and which led finally to definite proof of the existence of the electron and to precise measurement of the value of e. Aside from the great direct importance of these results, this account gives a valuable picture of the manner in which scientific results are achieved by painstaking effort in the face of apparently overwhelming obstacles. It was chiefly for this work and for his photoelectric work that Millikan was awarded the Nobel Prize in 1923. These were also among the grounds for the action of The American Society of Mechanical Engineers in conferring upon Millikan the A.S.M.E. Medal in 1926.

This account, and several of the chapters that follow it, are nearly reproductions of Millikan's earlier book "The Electron," published in 1924. While they cover such important topics as ionization, Brownian movements, the indivisibility of the electron, and the earlier theories of the structure of the atom (such as the Bohr theory), I will not dwell upon them, since they were presented in the earlier book and are comparatively well known.

The second half of the present book essentially dates from the year 1925, not only because the previous book by Millikan appeared in 1924, but also because the actual scientific progress reported in this second half, including such theoretical work as that begun by de Broglie in 1925 and the experimental work on cosmic radiation by Millikan and others, date from about that time. Thus Millikan's own work on cosmic rays began to emerge into definite form in 1925 with the completion of his first paper, which was printed early in 1926, and in which Millikan used the term "cosmic rays" for the first time.

Again in this part, mathematical investigation is mentioned rather than given, even in the chapters on waves and on the spinning electron; but some idea of the results achieved and their agreement with experiment, particularly on spectrographic evidence, is clearly stated.

In the discussion on cosmic rays, in which Millikan has played a central rôle, the account goes back to the earlier experiments of Gockel (as early as 1910), Hess, Kohlhörster, and others, and details the successive stages of experiment by these men and then by Millikan and Bowen, which led finally to the aforementioned paper (1925–1926) in which the origin of cosmic rays was shown very definitely to lie outside of our own solar system, and indeed outside of our own particular galaxy or star system. Full credit is given to the earlier experimenters who demonstrated the existence of unexpectedly powerful radiations coming to us from above and increasing as the distance from the earth's surface increases, and to the previous measurements by Kohlhörster (1923) of the penetrating power of these radiations.

Before a final discussion of the nature of cosmic rays, there intervene two chapters on the positron and the neutron. The positron (free positive electric charge of the mass of the electron) was discovered experimentally in 1932 by Anderson. The chapter shows the photographic evidence by photographs of the deflections under a magnetic field, secured by the usual Wilson cloud-chamber technique. The curvatures of the positron paths are seen in these photographs and are, of course, opposite to the curvatures of the paths of electrons in the same photographs.

In the few years since the discovery of the positron, an astounding amount of evidence has accumulated regarding the effects of bombardment of atoms by man-made projectiles, such as those produced by the million-volt tube of Lauritsen, and by the interesting ion-accelerating device of Lawrence. Other effects, of course, are produced by the natural bombardments whose source of energy is derived from radioactive materials or from cosmic rays. The whole picture of atomic structure has changed, since the existence of the positron makes necessary either the postulation of another fundamental non-electrified mass-particle (or neutron) or else the neutralization of a fundamentally (positively) charged proton by close union with it of a (negatively charged) electron. This essentially more complex structure of the atom and the evidence for one or the other of the hypotheses just mentioned appear in the chapter on the neutron.

As for the nature of cosmic radiation, the last chapter, which deals with this question, is illuminating in that it shows the growth of present ideas and the reasons for the gradual change from a preliminary hypothesis that cosmic radiation consisted almost wholly of gamma-type radiation with photons of energies of at most two or three billion electron-volts, to the present presumption that a considerable part of it, at least, consists of electrons endowed with energies up to ten billion electron-volts or more. This has forced the abandonment of the preliminary theory of the origin of cosmic radiation in the synthesis of matter in outer space. Little hint is given in this chapter of the controversies that have been waged, sometimes almost furiously, regarding this subject. The work of many men is recognized, including some reference to that of A. H. Compton, but the reader will not sense the considerable debate that has been had.

That views are changing rapidly is best illustrated by a comparison of this book (dated as of January, 1935) with the address delivered by Millikan himself at Pittsburgh at the Christmas meeting of the A.A.A.S. and printed in "*Science*" for March 1, 1935. In this address the discussion of cosmic radiation is leaning very much more toward the recognition of the existence of a considerable part that consists of electrons embued with enormous energies, even exceeding ten billion electron-volts. When one remembers that, as lately as 1910, the gamma rays from thorium C″, which have an energy of 2.6 million electron-volts, were regarded as extraordinary in energy, and that less than a decade ago Millikan seems to have held that energies above three billion electron-volts could hardly occur, the sudden change of ideas is apparent. One difficulty that now appears is to account for the enormous energies actually possessed by some electrons in cosmic radiation.

I shall venture the following suggestion. May it not be that atoms heavier than those known on this planet may exist, particularly in the extraordinarily "heavy" suns of which we now know? May not disintegration of these heavier atoms be a possible source of such tremendous energies as those mentioned? No ordinary spectroscopic evidence would be expected, since the atmospheres of the stars would ordinarily mask such effects. The "island-universes" provide a possible scene for chemical and radioactive processes, independent of our galaxy, that may be a possible explanation of the dilemmas with which we are left at the end of this stimulating book.

Whatever the future may hold of new discovery, the fundamental advances that are described in this volume will remain forever remarkable. Though many other scientists have contributed in great measure to these advances, the name of Millikan will undoubtedly be associated with them in the minds of all men.

Isaac Newton

ISAAC NEWTON—A BIOGRAPHY. By Louis Trenchard More. Charles Scribner's Sons, New York, 1934, Cloth, 6 × 9 in., 675 pages, frontispiece portrait and one diagram, $4.50.

REVIEWED BY W. F. DURAND[3]

THIS book is more than a biography of Sir Isaac Newton. It might almost be called a history of the development of scientific thought during the latter part of the seventeenth and the early part of the eighteenth centuries.

In addition to the great central figure, the reader is brought into contact with names such as Aston, Babington, Barrow, Bentley, Bishop Berkeley, John Bernoulli, Boyle, Tycho Brahé, Sir David Brewster, Cotes, De Morgan, Descartes, Flamsteed, Halley, Hooke, Huggins, Huygens, Leibnitz, John Locke, Voltaire, Sir Christopher Wren—to mention only a few of the characters which play some part, large or small, in the fascinating drama of the great awakening in the physical and mathematical sciences which characterized this period of time.

The bicentenary of the death of Sir Isaac Newton (March 20, 1927) gave occasion to note the fact that up to that time a satisfactory critical biography of this great scientific and mathematical genius was quite lacking.

Reference is made in the preface to the only biography of Newton which in any sense can be so styled—that written by Sir David Brewster and published in 1855. But Brewster was too near the time of Newton and perhaps was temperamentally ill fitted for the task of presenting the life and work of his subject with any fair sense of proportion or perspective. He is not presented to the reader as a human being but rather as "The High Priest of Science" and as such without flaw or blemish.

The author of the present work approaches his task in the more calm and measured attitude of a dispassionate analyst of the life and work of his subject, although generously tempered by a great and sincere admiration for Newton as a man and for his great achievements as a pioneer in science and scientific thought.

Newton's life naturally falls into three major subdivisions: his boyhood and early education, his life at Cambridge, and his later period of life as Master of the Mint in London.

The first period (1642–1661) is covered in a single chapter giving a pleasant picture of a rather quiet boy attending day school in the neighborhood until the age of twelve and then the "King's School" in Grantham for four years. He was then brought home to learn to be a farmer and to manage his mother's estate. The immediate cause of this was the death of Newton's stepfather whom his mother had married some years earlier, his own father having died shortly before Newton's birth. But Newton had no taste for such a calling in life, and finally he was sent back to Grantham to be tutored for college and from thence he went to Cambridge.

The second period (1661–1696) covers the productive period of Newton's life and is spread over some 400 pages of the book. No attempt can be made to give, in a review, any adequate picture of the author's treatment of this supreme period of Newton's life. His career as a student at Cambridge (of which but little is known), his appointment as a fellow and Lucasian Professor of Mathematics in 1669, his early discoveries in light and in infinite series as applied to various mathematical problems, his early reflections on gravitation dating from 1665, his invention of the reflecting telescope, his later experiments and arguments regarding the nature of light, his election to the Royal Society, his invention of the calculus by way of the method of fluxions and his long and regrettable controversy with Leibnitz over the question of priority, his later work on gravitation and its application to astronomical problems, and finally his *magnum opus*, the "Principia," written 1685–1687—these and many other minor phases of Newton's life are given judicial and scholarly treatment at the hands of the author.

The period of life at Cambridge, following the issuance of the first edition of the "Principia," was occupied largely with work in perfecting his lunar theory, with correspondence and controversy with Flamsteed, with work on corrections and notes for the "Principia" in the first edition of which there were many errors and some obscurity, and with divers other activities, some of which had no direct relation with his major scientific work.

The third period (1696–1727) is covered in its principal aspects by some seventy-five pages of the book with, in addition, chapters dealing with notable phases of Newton's life, such as his presidency of the Royal Society, knighthood and political activities, second edition of the "Principia," controversies with Flamsteed and Leibnitz, and studies in ancient chronology, theology, and religious beliefs.

In 1696 Newton was appointed Warden of the Mint with the duty of supervising and directing the work of recoinage of the coin of the realm. This work lasted for three years when Newton was promoted to the position of Master of the Mint, practically a sinecure, since his duties as such required his presence at the Mint offices only one day in the week. This position he held until his death in 1727 at the age of 85 years, full of life and the honors of which he was the recipient in these later years.

In this presentation of the life of Newton we are shown a man with the most divergent and surprising characteristics—a man with supreme intellectual powers, shy and retiring in his contact with others, deeply sensitive to criticism, insistent to the extreme in defense of what he considered his rights of priority and not always fair to those with whom he was in controversy; a man who felt that he had a proprietary right in his discoveries, a right to publish them or withhold them as he saw fit; a man who professed no joy in or love for his work and who had to be urged and pushed by others to put his great work the "Principia" into form; a man interested in alchemy and the philosophers' stone; a man of deep religious feeling though of questionable accord with the orthodoxy of the day; a man who spent much of his time in his later years in the study of the chronology of biblical and profane history based on Archbishop Usher's date of the Creation as 4004 B.C.; a man interested in spending long hours of study over the interpretation of the book of Daniel and of the Revelations.

These are some of the sides of the man Newton as they are shown to us in this biography. On the whole Newton's character may be summarized as basically generous, pure-minded, pious, and self-disciplined. But with this we must attempt to reconcile modesty with his own assurance of the superiority of his discoveries; intellectual integrity with his uncertain temper and inconstancy of conduct; stiff insistence on an exclusive right and title to his ideas which he kept secret, with indifference, even repulsion, toward popular fame; high moral principles with treatment of rivals which was not always generous or fair.

In his relations with the outside world, Newton seemed to be lacking in any desire or sense of obligation to disclose to others the fruits of his study. He had small sense of obligation to the world or to the university which had so generously supported him, and the consequences of fame, bringing with it the probability of criticism, were so repugnant that time and again he protested that he would abandon science or would at least withhold his work from publication until after his death.

Newton's controversies with his contemporaries seem to have bulked large in the routine of his scientific life. Those with Hooke, Flamsteed, and Leibnitz are the most conspicuous for their length, vigor, and acrimony. His controversy with Hooke turned chiefly on various matters relating to light and optics, and it seems to have delayed the publication of Newton's "Optics" for thirty years and even hazarded the completion of the "Principia."

His controversy with Flamsteed seems to have started with the question of whether the latter had properly and adequately furnished Newton with copies of his observations on the moon as a foundation for the further development and improvement of his "moon theory." There was obviously fault on both sides, but Newton's part was one which must have given little satisfaction to his friends.

The controversy over priority in the invention of the calculus is perhaps the most notable in all scientific history. It is set forth in great detail by the author, supported by copies of numerous letters. No review can attempt to give even an outline. In the end, however, it seems clear that Newton and Leibnitz each in his own way independently made this epoch-making mathematical discovery. Newton was first in point of time, but, refusing to publish, and, somewhat after the fashion of medieval times, choosing rather to hide what he considered a key to the discovery in a jumbled Latin sentence, he lost the opportunity of seeing his methods first put to use. Leibnitz, on the other hand, published freely, and it is only fair to say that the development of mathematics, especially in continental Europe, immediately took form around this new and powerful tool.

Newton's closest friend was Edmund Halley, the astronomer, also assistant to the secre-

[3] Professor Emeritus, Mechanical Engineering, Stanford University, Stanford University, Calif Past-President, A.S.M.E.

taries of the Royal Society. Halley, younger than Newton, came early under the influence of his great master and for long years was his staunch friend and defender. This in the end developed into the position of editor of the "Principia" when the time finally came for seeing it through the press. Halley's personal financial obligation in this undertaking, Newton's indifference to this phase of the publication, Halley's trouble with paper, with proof, with the continuing controversy between Newton and Hooke, with Newton's threat to suppress the third book—these and many other incidents are set forth in the chapter dealing with this critical phase of Newton's life.

Newton had, early, come under the notice of members of the Royal Society, and in 1671 he was elected member. However, in 1672, presumably irritated by controversies with certain members and piqued by what he considered rude treatment, he resigned his membership in the society, a resignation which was not accepted and which he did not force. Years later when the society received the "Principia" with high acclaim, he recovered in a measure some of his wounded feelings and finally with the passing of Hooke accepted the office of president of that select body.

Quite aside from his supreme genius in mathematics and mechanics, Newton was skilful in the highest degree with his hands and in the use of such tools as his age afforded. He showed this in early years in the making of models and toys; later he became expert in the figuring, grinding, and construction of lenses and of reflecting mirrors. In fact, his earliest definite impression on the Royal Society seems to have been through a small reflecting telescope which he himself made and submitted for their examination.

We obtain another picture of Newton the man, in the evidence of his interest in small things. He was generous financially in helping community affairs and in contributing to public enterprises, but withal retained the countryman's attitude lest he be overreached in small affairs. Thus when he was well on in years he took time to settle just how many cows and sheep he was entitled to have graze on the common. Again when he was immersed in the composition of the "Principia," he took the time to write a long letter going into minute details regarding the repairs to a house and barn and threatening his tenants with a lawsuit if they did not mend their ways.

He was not interested in travel and lived almost constantly in his quarters in Trinity College or later at his house in London. It was only when he was approaching 80 years of age that he visited Oxford.

Newton never married. During a period of nearly two years when the University was closed on account of the great plague (1665–1667) Newton lived at Woolsthorpe where he seems to have become engaged to a Miss Story. Later when he returned to Cambridge this engagement was broken off or perhaps gradually faded away. A fellowship in Cambridge was in immediate sight; to marry would mean renouncing all chance of such preferment or of the life as it was then opening up before him at Cambridge. There was, in any event, no violent rupture. Newton and Miss Story remained for life, warm and devoted friends.

Newton in his older years is pictured to us by Conduitt (with whom he lived in old age) physically as having a "lively and piercing eye, a comely and gracious aspect, with a fine head of hair, white as silver, without any baldness." Others describe him differently. Thus Bishop Atterbury: "In the whole of his face and make, there was nothing of that penetrating sagacity which appears in his compositions; he had something rather languid in his look and manner which did not raise any great expectation in those who did not know him." Or again Hearne says: "Sir Isaac was a man of no very promising aspect. He was a short well-set man. He was full of thought and spoke very little in company, so that his conversation was not agreeable."

This biography as a whole shows a prodigious amount of research and labor on the part of the author. All available sources have been drawn on including the famous Portsmouth collection, the British Museum, and many private sources. The picture of the life and times of this period is rendered more vivid by the inclusion in the text of some 115 letters passing between the characters on the stage of this great drama.

It is not easy to characterize properly a monumental work of this character. The author has set as his task the writing of an adequate critical biography of this great figure in the development of science and the scientific method. This task he has certainly accomplished. There is a certain amount of repetition in the 668 pages of the text which might have been avoided by a somewhat different arrangement and treatment of the material. Again the picture might have been made perhaps a little sharper by a condensation to one-half the number of pages. Such a picture would, however, have lost much in the way of picturesque detail and in the background values which add so vastly to the sense of reality gained by the reader if only he will take the time to go through the work from cover to cover as it is. The present reviewer has no fault to find with this wealth of detail. The great central figure in the advance of modern mathematical and physical science surely merits a biographical treatment in such detail as to meet the tastes of those who may wish, in a life of Newton, a fully satisfying picture of the life and times in which he lived and wrought.

It is true that the perusal of this book will remove some of the illusions which we may have cherished regarding this great man. He was a man of gigantic intellect but coupled therewith were what to us seem strange and inconsistent inhibitions and limitations. After all, aside from his great intellect, he is shown as a man much like ourselves. Perhaps in human interest he gains thereby.

The author is to be congratulated in coming to the end of his long and arduous labors and in having given to the world a book which will long stand as a monument to his patience, erudition, and good judgment, as well as a revelation to the present and future ages of the life and times of this great pioneer in the development of modern science.

Books Received in Library

(The) BOOK OF STAINLESS STEELS, Corrosion-Resisting and Heat-Resisting Chromium Alloys. Edited by E. E. Thum. Second edition. American Society for Metals, Cleveland, O., 1935. Cloth, 6 × 9 in., 787 pp., illus., diagrams, charts, tables, $5. Although it is only two years since this book appeared, this new edition contains one-fourth more pages than its predecessor. The book contains the combined experience of seventy-five specialists in the manufacture and use of heat and corrosion-resisting steels. The subject is discussed from the viewpoints of the production and fabrication of these steels, the properties of the typical alloys, specialized tests for corrosion, creep and endurance, and the requirements of various industries. A useful list of trade names and a directory of manufacturers is included.

CORROSION, CAUSES AND PREVENTION. By F. N. Speller. Second edition. McGraw-Hill-Book Co., New York and London, 1935. Cloth, 6 × 9 in., 694 pp., illus., diagrams, charts, tables, $7. This treatise, which is based upon a thorough examination of the existing literature and on the extensive experience of the author, is a comprehensive review of the subject, especially with reference to the ferrous metals. The nature of corrosion, the influence of various factors, and the prevention of corrosion by air, water, steam, chemicals, and electricity are discussed. A selected bibliography is included. This edition has been revised.

CRUSHERS FOR STONE AND ORE. By W. T. W. Miller, with an introduction by Sir R. Hadfield. Mining Publications, Ltd., London, 1935. Cloth 6 × 9 in., 234 pp., illus., diagrams, charts, tables, 15s. The author of this book, who was for many years the engineer-in-charge of the crusher department of the Messrs. Hadfields, Ltd., has had a long experience in the design and construction of crusher plants for a wide variety of purposes. The present work gives the results of his experience with different types of crushers, shows their development, characteristics, and capabilities and contains much of interest to designers and operators. Much of the material appeared in various periodicals.

DAUERFESTIGKEITSVERSUCHE MIT SCHWEISSVERBINDUNGEN. Bericht des Kuratoriums für Dauerfestigkeitsversuche im Fachausschuss für Schweisstechnik beim Verein deutscher Ingenieure, durchgeführt 1930 bis 1934. V.D.I. Verlag, Berlin, 1935. Paper, 9 × 12 in., 46 pp., illus., diagrams, charts, tables, 8.50 rm. In 1930 the Welding Committee of the Verein deutscher Ingenieure undertook an elaborate investigation of the fatigue resistance of welded joints. Experiments were made in various laboratories during the next four years, which are described in this report, with the conclusions derived from them. The report is an important contribution on the behavior of welded connections in bridges and other structures.

DINAMOMASHINA V EE ISTORICHESKOM RAZVITII (Dynamo-Electric Machine in Its Historical Development). Documents and materials collected by D. V. Efremov and M. I. Radovskij; edited by V. Th. Mitkevitch. Academy of Sciences Press, Leningrad, 1934. Cloth, 7 × 10 in., 560 pp., illus., diagrams, charts, tables. This volume, published by

the Institute for the History of Science and Technology of Leningrad is composed of translations in Russian of the basic papers on the dynamo. Seventy-seven articles are included, beginning with Faraday's announcement of the discovery of electromagnetic induction in 1832, and ending with the classic investigation of the dynamo by the Hopkinsons in 1887. The papers, published in chronological sequence, afford an excellent survey. A classified index is provided, and a biographical index of authors.

FORSCHUNGSHEFT 371. Reibungs- und Undichtigkeitsverluste an Kolbenringen. By M. Eweis. V.D.I. Verlag, Berlin, 1935. Paper, 8 × 12 in., 23 pp., illus., diagrams, charts, tables, 5 rm. A report upon an experimental study of frictional and leakage losses through piston rings. The report first surveys the varieties of friction on the basis of previous studies, and then discusses the question of the distribution of pressure behind piston rings. Finally, the author's experiments and their results are presented in detail.

GLASS FACTORY YEAR BOOK AND DIRECTORY. 1935 edition. American Glass Review, Pittsburgh. Leather, 5 × 8 in., 159 pp., illus., tables, $3. The directory lists the American manufacturers of glass and glassware and the trade and workmen's associations, and gives statistics upon production and consumption. A buyers' guide to materials and equipment is also included. The information about factories includes the names of officers, equipment and products.

JAHRBUCH DER BRENNKRAFTTECHNISCHEN GESELLSCHAFT E. V. Vol. 15, 1934. Wilhelm Knapp, Halle (Saale), 1935. Paper, 8 × 11 in., 72 pp., illus., diagrams, charts, tables, 8 rm. The yearbook presents the papers before a meeting in December, 1934, which was devoted to the subject of gas. The papers discuss gas works in the light of modern economic conceptions; stationary and vehicular gas engines; liquefied gases as automobile fuels; gas oil; present use of methane in automobiles; gas in industry, trade and the home; and non-poisonous gas.

MANUAL OF ENGINEERING DRAWING FOR STUDENTS AND DRAFTSMEN. By T. E. French. Fifth edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 481 pp., diagrams, charts, tables, $3. A college textbook based upon the "conception that drawing is a real language, to be studied and taught in the same way as any other language." The course is comprehensive, including chapters on architectural and map drawing, as well as on numerous allied topics. This edition has been enlarged by a new chapter on sections and conventions, and new material on dimensioning. It has also been made to conform to the standards of the American Standards Association. A useful bibliography of allied subjects is included.

(THE) MAN WHO BUILT THE "MAURETANIA," Big Ships and Great Ideals, the Life Story of Sir George B. Hunter, K.B.E., D.Sc. (Great Britain's Master Craftsman.) By W. Rutherford; a foreword by Lord Kirkley. Hillside Press, London, 1935. Cloth, 6 × 9 in., 170 pp., 7s 6d. This is a biographical sketch of Sir George B. Hunter, who for fifty years was the active head of one of the great shipbuilding firms of England. The volume describes his personal and professional life and gives some account of his views upon spelling reform, trade unionism, tariffs, and other political and social problems.

(A) SOURCE BOOK IN PHYSICS. By W. F. Magie. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 620 pp., diagrams, tables, $5. This volume contains extracts from important contributions made to physics during the period between the introduction of the science of dynamics by Galileo, about 1600 A.D., and the introduction of the quantum theory by Planck, in 1900. The work is intended to make accessible to students the most significant portions of the original papers in which important discoveries or methods of thought were announced. The extracts are accompanied by brief biographical sketches and are grouped in the customary divisions of the science.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of May 24, 1935, and approved by the Council.

CASE NO. 780 (REOPENED)

(Special Rule)

Inquiry: The use of the high-strength copper-alloy material covered in the inquiry in Case No. 715, which is allowed by the reply to that Case a working stress of 9000 lb per sq in., results in too great a weight for a seamless forged pressure vessel (annealed, if required to obtain specified properties) when computed at that stress for use for high-pressure purposes at very low temperatures. Will it be acceptable, under the Code rules, to compute the working pressure of such seamless vessels fitted with bolted covers to operate in low-temperature service on the basis of a stress allowance of 11,000 lb per sq in., provided that any openings in the cylindrical portion of the shell are adequately reinforced under the rules in Par. U-59? The material in such vessels will be the same as that referred to in Case No. 715 except that the elongation requirement is lowered to 50 per cent and the reduction requirement to 60 per cent. It is pointed out that the ultimate strength and the elastic limit of this material is considerably improved at low temperatures.

Reply: In view of the data submitted, it is the opinion of the Committee that the material referred to, if used in seamless forged vessels fitted with bolted covers with all openings in the shell adequately reinforced, will give safe results at sub-zero temperatures under a working stress of 11,000 lb per sq in.

CASE NO. 804

(Special Rule)

Inquiry: Is it permissible, under the requirements of the Code, to fusion weld superheater tubes complying with Specifications S-17, up to a maximum diameter of $2\frac{1}{2}$ in. to tubular manifolds or headers? The welds will be strength welds similar to Fig. P-7*c* and the tubes would not be expanded. The welding would be equivalent to that required under the rules in Pars. P-101 to P-111 and X-ray examination would be omitted. The elements would be stress-relieved after welding. Inquiry is also made whether, under these conditions, it would be necessary to hammer test such welds in accordance with Par. P-109, or would a hydrostatic test of twice the working pressure be sufficient?

Reply: It is the opinion of the Committee that the rules for attaching nozzles by fusion welding as given in Par. P-268*b* may be used for attaching superheater tubes to tubular manifolds or headers. It is also the opinion of the Committee that as the hammer test is not required for small nozzles it is not necessary to hammer test these welds. A hydrostatic test of twice the working pressure, subject to any necessary modifications due to temperature requirements in accordance with Table P-8, will meet Code rules.

WHAT'S GOING ON

This Month's Authors

THE evolution of a new type of steam generator from an exhaust-gas turbine is the tale told by Dr. Adolphe Meyer, director of the steam-turbine department of Brown, Boveri & Company, Baden, Switzerland. Dr. Meyer has been visiting in the United States. In June the Stevens Institute of Technology conferred on him the honorary degree of Doctor of Engineering. His paper was delivered at Cincinnati as the Calvin W. Rice Memorial Lecture.

How more conservative arts of railroading progress as a result of the more recent arts of aeronautics is illustrated in the description of the high-speed Diesel-electric train, the "Comet," provided by the famous Zeppelin designer, Dr. Karl Arnstein, member A.S.M.E. Born and educated abroad and formerly connected with the Zeppelin Company, Friedrichschafen, where he designed more than 70 airships, including the *Los Angeles*, he came to this country in 1924 as technical director of aircraft construction for the Goodyear Tire and Rubber Co., Akron. Here he designed the airship dock, and the sister ships *Akron* and *Macon*. The descriptive portion of Dr. Arnstein's paper, published this month, will be followed by a second part devoted to the structural design and strength of the train and the mechanics of the train in motion. The paper was presented in May at New Haven before a local group of mechanical and electrical engineers.

Professors Eidmann, Shoudy, and Baumeister are members of the Curriculum Committee of the Department of Mechanical Engineering, Columbia University, New York, and members of the A.S.M.E. All three are engaged in consulting practice as well as teaching. Professor Eidmann's specialties are machine design and production engineering, Professor Shoudy's steam turbines and power plants, and Professor Baumeister's thermodynamics and power engineering. All have served and are now serving on A.S.M.E. Committees. A more complete report of their curriculum study was presented at the Atlanta meeting of the S.P.E.E.

The stimulus that Frederick W. Taylor, past-president, A.S.M.E., gave to fundamental research in the cutting of metals persists vigorously to this day. Messrs. Ernst and Martellotti have had the advantage of techniques in research that were unavailable to Taylor, and have made good use of them in recording photographically the mechanism of the so-called built-up edge of a metal-cutting tool. Both authors are engaged in research at the Cincinnati Milling Machine Co., Cincinnati, Ohio. Mr. Ernst was graduated from the Melbourne Technical College, Melbourne, Australia, 1911, and Mr. Martellotti from the Royal Polytechnic Institute, of Milan, Italy, 1922. Mr. Ernst is a member and Mr. Martellotti an associate-member of the A.S.M.E.

F. H. Rogers and R. E. B. Sharp, members, A.S.M.E., and chief engineer and hydraulic engineer, respectively, of the I. P. Morris Division, Baldwin-Southwark Corporation, Philadelphia, Pa., write on the hydraulic turbines designed for the Wheeler Dam on the Tennessee River. Mr. Rogers was graduated from the University of Pennsylvania and Mr. Sharp from Tulane University, both in 1906, and both commenced their present connections (Mr. Sharp through Cramps) upon graduation.

Dr. Irving Langmuir, Holley Medalist for 1934, is a distinguished scientist and recipient of innumerable honors. He makes it a practice to inquire about everyday phenomenon which every one observes but no one understands. His critical curiosity has led to amazingly useful discoveries. The citation in connection with the award of the Holley medal reads: "Contributions to science and engineering, especially in the development of the gas-filled incandescent lamp, of the thoriated filament for thermionic emission, of atomic-hydrogen welding, of phase-control operation of the thyratron tube, and in fundamental research in oil films."

This month's review of economics literature from the Economics Department of the Massachusetts Institute of Technology, under the sponsorship of the A.S.M.E. Management Division is by Donald S. Tucker professor of economics in that department.

Nominations for Officers of A.S.M.E., 1935–1936

AT THE Semi-Annual Meeting of The American Society of Mechanical Engineers at Cincinnati, Ohio, June 17 to 21, 1935, the Nominating Committee reported the following nominations for officers of 1935–1936, to be voted on by letter ballot in the early fall:

For president, William L. Batt; for vice-presidents, Alex D. Bailey, John A. Hunter, William A. Shoudy, and R. L. Sackett; for managers, William Lyle Dudley, W. C. Lindemann, and James W. Parker. Brief biographical sketches of the nominees follow.

William L. Batt

WILLIAM L. BATT, nominated for the office of President of The American Society of Mechanical Engineers, is president of the SKF Industries, Inc. Mr. Batt was born in Salem, Ind., in 1885. His family later moved to Lafayette, where he attended the public schools, and eventually Purdue University, from which he was graduated in 1907 in mechanical engineering.

Prior to his graduation and for a short time thereafter, Mr. Batt was associated with Dr. W. F. M. Goss, then Dean of Engineering of Purdue, in the private professional work which Dean Goss then carried on. With Dr. Goss's departure from Purdue Mr. Batt became associated with The Hess-Bright Manufacturing Company, Philadelphia, in manufacturing, engineering, and sales of anti-friction bearings. In 1917 he became general manager of the company, and following the consolidation of the SKF Ball Bearing Company, The Hess-Bright Manufacturing Company, and other organizations, became vice-president of SKF Industries, Inc., the central organization. He has held the office of president since 1922.

Mr. Batt has been a member of The American Society of Mechanical Engineers since 1911, and has been actively interested in its work, serving as chairman of the Revenue Committee, chairman of the Committee on Meetings and Program, chairman of the Coordination Committee of Engineering Societies, U.E.T., Inc., and as a member of the Market Analysis Committee, and of the Committee on Awards. He is at present a vice-president of the Society. He is also interested in committee work in the Society of Automotive Engineers.

Mr. Batt is also a director of the Air Preheater Corporation and a director of the Hudson Insurance Company, New York. In 1923 he was elected a member of the Board of Directors of the Swedish Chamber of Commerce of the U.S.A., and in 1926 was elected vice-president. For his interest and activity in promoting commercial relations with Sweden, King Gustav V, of Sweden, in 1926, conferred upon Mr. Batt the decoration of the Order of Vasa, and in 1933 the Royal Order of the North Star.

He is a member of the Tau Beta Phi honorary fraternity, the Purdue Club of New York, the Engineers' Club, New York, the Upper Montclair Country Club, and the Pine Valley Golf Club. In November, 1933, he was honored by his Alma Mater, Purdue University, with the degree of Doctor of Engineering.

He has contributed a number of articles to technical and general publications.

Alex D. Bailey

ALEX D. BAILEY, nominated for the office of Vice-President of The American Society of Mechanical Engineers, is assistant chief operating engineer, Commonwealth Edison Co., Chicago, Ill. He was graduated from Lewis Institute in 1903 with the degree of M.E. and in that same year entered the employ of the Commonwealth Edison Co., where he has served in the engineering and operating departments.

Mr. Bailey has been a member of the Society since 1916. He is at present a manager of the Society, and chairman of the Advisory Board on Standards and Codes and has served as a member of the Main Research Committee and of the Power Test Code Committee on Stationary Steam-Generating Units. He is a past-chairman of the Chicago Section of the Society as well as past-chairman of the Power Division. He has been active in work for the National Electric Light Association, having served as chairman of the Prime Movers Committee, the Research Committee, and the Engineering National Section. Mr. Bailey has also been interested in the conduct of the Mid-West Power Conferences.

John A. Hunter

JOHN A. HUNTER, nominated for the office of Vice-President of The American Society of Mechanical Engineers, is professor of mechanical engineering at the University of Colorado. He was graduated from Pennsylvania State College in 1890 with the degree of B.S. in mechanical engineering, and then spent three years in manual training schools in the South. In 1894 he returned to take graduate work at Pennsylvania State College and Cornell University, receiving the degree of M.E. in 1896 from the former institution.

Until 1904 Professor Hunter served as instructor and assistant professor of mechanical engineering at Pennsylvania State College, resigning at the end of that period to accept the position of assistant professor of mechanical engineering at the University of Colorado in charge of the departments of mechanical and chemical engineering. In 1906 he was appointed a full professor of mechanical engineering and director of chemical engineering, which position he now occupies.

Professor Hunter's vacations from 1896 to 1918 were spent in practical work in some of the leading manufacturing plants of the country, including the Westinghouse Machine Works, the Pittsburgh Locomotive Works, the Baldwin Locomotive Works, and the Pennsylvania Railroad.

He has been a member of the A.S.M.E. since 1914 and has been exceedingly active in the work of the Colorado Section of the Society, not having missed a meeting since its establishment in 1918. He is at present a manager of the Society. He is also a member of the Society for the Promotion of Engineering Education, of Alpha Chi Sigma, Pi Tau Sigma, and an honorary member of Tau Beta Pi. He has been a member of the Colorado Board of Examiners for Engineers and Land Surveyors since 1921; has served on the Boulder City Council from 1912 to 1916; and has been a director of the Boulder Chamber of Commerce for many years, serving as its president for three years.

William A. Shoudy

WILLIAM A. SHOUDY, nominated for the office of Vice-President of The American Society of Mechanical Engineers, is associate professor of mechanical engineering at Columbia University and a practicing consulting engineer associated with Geo. A. Orrok and David Moffat Myers, of New York City.

He was born in Brooklyn, April 5, 1878, and was educated at Adelphi Academy and Stevens Institute of Technology, where he was graduated in 1899. After four years of junior engineering work he returned to Stevens as instructor in experimental engineering under Dr. D. S. Jacobus. Later as assistant professor of engineering practice, he was assistant to Dr. James E. Denton. He resigned in 1911.

He has been successively mechanical assistant of the Baltimore Smelting and Refining Co.; engineer of tests, Brooklyn Edison Co.; assistant mechanical engineer for the J. G. White Engineering Corporation; power engineer for the American Sugar Refining Co.; superintendent of steam stations and advisory engineer of the Adirondack Power & Light Corporation, Amsterdam, New York. He has served as advisory engineer for the National Public Service Corporation and consulting engineer of the M. H. Detrick Co., the Bailey Meter Co., and the New York Steam Corporation.

Mr. Shoudy has been a member of The American Society of Mechanical Engineers since 1903. He is now chairman of the A.S.M.E. Committee on Professional Divisions, past-chairman of the A.S.M.E. Committee on Publications, and member and chairman of several special committees. In 1933 he was chairman of the Professional Engineers' Committee on Unemployment. He has contributed several technical papers to the Society publications.

He is a member of Sigma Xi and Phi Sigma Kappa.

R. L. Sackett

R. L. SACKETT, nominated for the office of Vice-President of The American Society of Mechanical Engineers, is dean of the School of Engineering at Pennsylvania State College. He was graduated from the University of Michigan in 1891 where he studied under Dean M. E. Cooley, later a president of the Society.

After graduation he entered the government service in the River and Harbor Survey work on the Great Lakes and was employed on the investigation of the Grand River. He started his teaching career as professor of mathematics and mechanics at Earlham College, Richmond, Ind., continuing his engineering practice which later included the design of water-works plants for cities and Indiana state institutions.

In 1907 Dean Sackett was appointed professor of hydraulic and sanitary engineering at Purdue University, where he planned the hydraulic laboratory and carried on various investigations in it. He was consultant to the State Board of Health and by appointment by governors was consulting engineer to various commissions and state institutions on water-pumping and power-generating plants. He was also employed to give expert testimony for railroads and other corporations. In 1915 he became dean of the School of Engineering at Pennsylvania State College. Dean Sackett is a past-president of the Society for the Promotion of Engineering Education and a past vice-president of the American Association for the Advancement of Science. He was chairman of the S.P.E.E. Committee on Instruction in Industrial Relations, and of the A.S.M.E. Committee on Education and Training for the Industries and is a member of the Committee on Education of the A.S.C.E. He is also chairman of the Committee on Selection and Guidance of Engineering Students of the Engineers' Council for Professional Development. He is the author of "The Engineer, His Education and Training," as well as of many articles published both in the technical press and in educational magazines.

He has been a member of the A.S.M.E. since 1915. He is also a member of the American Society of Civil Engineers, a fellow of the A.A.A.S. and the S.P.E.E., a member of Sigma Xi, Tau Beta Pi, as well as of several other organizations.

William Lyle Dudley

WILLIAM LYLE DUDLEY, nominated for the office of Manager of The American Society of Mechanical Engineers, is vice-president and chief engineer of the Western Blower Co., Seattle, Wash. Mr. Dudley was born in Portland, Ore., in 1894. He attended the University of Washington from which he was graduated in 1912 with the degree of B.S. in mechanical engineering. In 1926 he received the degree of M.E.

Upon graduation he became associated as sales engineer with the Cromwell Manufacturing Co., with particular interest in the design of heating and ventilating installations. Two years later he resigned to enter the bridge-engineer's department of the County of King, Seattle, where his work dealt with bridge drafting and design. The following year he became engineer for the Western Blower Co. From 1915 to 1920 Mr. Dudley had charge of all engineering work in designing, developing, and installing air-conveying, heating and ventilating, humidifying, and similar systems. Later he became chief engineer of the company and then vice-president.

During the War Mr. Dudley served in the U. S. Army, holding the rank of captain in infantry. He became a member of The American Society of Mechanical Engineers in 1921 and is at present finishing a five-year term with the Standing Committee on Local Sections, being chairman this year. He is also a member of the American Society of Heating and Ventilating Engineers and of the Society of American Military Engineers. He is responsible for promulgating the Engineers Registration Law for the State of Washington which takes effect this year. Mr. Dudley is the author of a book on "Approach to Sub-Atomic Physics," and of technical papers.

W. C. Lindemann

W. C. LINDEMANN, nominated for the office of Manager of The American Society of Mechanical Engineers, is works

Nominated for

A.S.M.E. OFFICERS IN 1935–1936

For President

WILLIAM L. BATT

For Vice-Presidents

ALEX D. BAILEY

JOHN A. HUNTER

R. L. SACKETT

WILLIAM A. SHOUDY

WILLIAM L. BATT

For Managers

WILLIAM LYLE DUDLEY

W. C. LINDEMANN

JAMES W. PARKER

Biographical sketches of the candidates will be found on pages 527-531 of this issue.

WILLIAM A. SHOUDY

R. L. SACKETT

ALEX D. BAILEY

JOHN A. HUNTER

JAMES W. PARKER

WILLIAM LYLE DUDLEY

W. C. LINDEMANN

manager and secretary of the A. J. Lindemann & Hoverson Co., Milwaukee, Wis. Mr. Lindemann was born July 5, 1887, in Milwaukee, Wis., where he received his early education. He was graduated from the University of Wisconsin in 1908 with the degree of B.S. in mechanical engineering, and then spent a year in post-graduate work at Charlottenburg Hochschule.

In the fall of 1909 he became associated with the A. J. Lindemann & Hoverson Co. as chief engineer, and together with the duties of that position, took charge also of a number of production departments, one after another, until 1917. In that year he became works manager of the entire plant, and a short while later, secretary.

In 1913 Mr. Lindemann became an associate-member of The American Society of Mechanical Engineers and in 1921 was advanced to full membership. He has served in several offices of the Milwaukee Local Section and has been a member of the Nominating Committee of the Society on two different occasions. He is also a member of long standing of the Engineering Society of Milwaukee in which he has been active in committee work, serving as a director several times, and as president. Mr. Lindemann is at present, and has been for the past six years, the representative on the American Engineering Council of the Engineers' Society of Milwaukee. He has been a member of the American Ceramic Society for fifteen years and is a member of its Board of Directors.

James W. Parker

JAMES W. PARKER, nominated for Manager of The American Society of Mechanical Engineers, is vice-president and chief engineer of The Detroit Edison Company, and has his residence in Ann Arbor, Michigan. He was born in Auburn, New York, in 1886, of people who had lived in that state for a generation or more but had come originally from New England. His family moved to Kentucky when he was four years old and his boyhood was spent in Louisville.

He prepared for college in the Louisville Male High School and then was graduated from Cornell University in 1908, with the degree of mechanical engineer. In 1935 he was awarded the honorary degree of master of science in mechanical engineering by the Detroit Institute of Technology. He is a member of Sigma Xi and Tau Beta Pi.

After graduation from Cornell, Mr. Parker served an apprenticeship first with the DeKalb Power and Light Company, DeKalb, Ill., and then with the Vincennes Street Railway Company, Vincennes, Ind. In 1910 he moved to Detroit to become boiler-room engineer with The Detroit Edison Company, and has been employed continuously by that Company to the present time, with the exception of a year's leave of absence for War Department service in 1918.

In the course of this employment he has organized and directed the various engineering projects which his company has accomplished in the last twenty years, notably the design and construction of its electric power plants, Trenton Channel, Marysville, Delray No. 3, and Conners Creek. In addition to supervising new construction, Mr. Parker has also general responsibility for the operation of the Detroit Edison electrical system and of its generating plants and central heating plants and system.

He has served since 1929 as a Trustee of Cornell University, elected by the alumni and reelected in 1934. Since 1933 he has been Chairman of its Engineering College Council, a group of engineering alumni which has come to be an effective influence in the life of the College of Engineering at Cornell.

During the World War he served in the Nitrate Division of the Ordnance Department, United States Army, as consulting mechanical engineer and head of that Division's inspection section.

Mr. Parker has been a member of The American Society of Mechanical Engineers since 1913. From 1928 to 1933 he served as member and Chairman of the Committee on Meetings and Program, and is at present a member of the Committee on Policies and Budget. He is a member of The Detroit Engineering Society, the Michigan Engineering Society, and the Prismatic Club of Detroit.

A.I.E.E. Elects Officers

E. B. MEYER, chief engineer, Public Service Electric & Gas Co., Newark, N. J., was elected president of the American Institute of Electrical Engineers for the year beginning August 1, 1935, at the annual meeting of the Institute held at Ithaca, N. Y. The other officers elected were: Vice-Presidents, W. H. Harrison, Philadelphia, Pa.; Mark Eldredge, Memphis, Tenn.; R. H. Fair, Omaha, Neb.; N. B. Hinson, Los Angeles, Calif.; C. V. Christie, Montreal, Canada. Directors, C. R. Jones, New York, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; G. C. Shaad, Lawrence, Kans., member A.S.M.E. National treasurer, W. I. Slichter, New York, N. Y., member A.S.M.E., reelected.

A.S.M.E. Council Meeting at Cincinnati

ON TUESDAY, June 18, prior to the opening of the technical sessions of the Semi-Annual Meeting of The American Society of Mechanical Engineers, in Cincinnati, Ohio, the Council convened at the Hotel Gibson. The following actions are of general interest.

JOHN C. PARKER CASE

The Secretary outlined the situation in the investigation of the Society's affairs instigated by John C. Parker. To date only Mr. Parker's side of the case has been presented to the referee. A full account and a résumé of the nine hearings have been submitted to the Council and a résumé of subsequent hearings will be sent to every Council member as soon as possible after each hearing. In view of the fact that the case is still before the referee it was deemed improper to appoint a committee to review the evidence until all of it has been heard and the referee has rendered his decision. At the close of the hearings and submission of the referee's report, it is the intention of the Council to render a full account of the case to the members.

BUDGET FOR 1935–1936

For the Finance Committee, W. D. Ennis presented a statement of policies and a schedule of income and expense for 1935–1936. After an exhaustive discussion, in which representatives of the numerous Society committees were given full opportunity to present their requests and comments on every item, the schedule, with certain modifications, and the statement of policies were adopted. It was voted to continue the Society's Mid-West office in Chicago, and to omit publication of the Membership List in 1935–1936. Increased appropriation to the American Engineering Council for 1935–1936 was voted, if financial conditions shall permit.

REVISION OF CONSTITUTION AND BY-LAWS

Proposed changes in the Constitution and By-Laws relating to membership grades were discussed. [The changes in the Constitution were subsequently acted upon at the Business Meeting, and may be found, as there approved, in the account of that meeting, p. 532.]

POLICIES AND BUDGET COMMITTEE

Harry R. Westcott, chairman, Committee on Policies and Budget, reported (1) that further study was being made of the reorganization of the A.S.M.E. Council on the basis of geographical distribution; (2) that the organization of committees on Honors and Awards and on Cooperative Relations, and the advisory boards on Technology and on Standards and Codes had been completed; and that an advisory board on Professional Status had also been established.

MEETINGS AND PROGRAM

Robert I. Rees, chairman, Committee on Meetings and Program, outlined the plans for a change in policy regarding the social events of the A.S.M.E. Annual Meeting: (1) To hold the Presidents' reception at the Annual Banquet, between the speeches and the dancing; (2) to arrange an "Honors Night" on Tuesday evening at which all honors and prizes will be awarded, and at which either the Towne or the Thurston lecture will be delivered. It was suggested that the President's address would probably be delivered at the banquet.

Upon recommendation of the Committee on Meetings and Program with the concurrence of the Committee on Local Sections, it was voted to hold the 1936 Semi-Annual meeting in Dallas, Texas, during the third week in June, and a Regional Meeting, under the auspices of the Buffalo Section, probably at Niagara Falls, in June or September, 1936.

PUBLICATIONS

S. W. Dudley, chairman, Committee on Publications, presented a comprehensive report on publications, discussion of which was scheduled for the October, 1935, meeting of the Council, at which questions of policy are to be discussed.

At the suggestion of the Committee on Publications special committees were authorized to study the "Mechanical Catalog" and to study the relationship of dues income and publication service rendered to members.

HONORS AND AWARDS

Upon recommendation of the Committee on Honors and Awards it was voted to receive a proposed amendment to the By-Laws establishing a Board on Honors and Awards of five members. It was also voted to approve a Medal Committee of 20 members, five of whom shall be members of the Board of Honors and Awards.

REGISTRATION OF ENGINEERS

It was voted to adopt the following policy on registration:

(1) The A.S.M.E. will present the broad aspects of registration to its members in those states not having registration and stimulate its consideration by them.

(2) The A.S.M.E. will not publicly urge registration in those states where the movement has not taken definite shape.

(3) In those states where a registration movement has been initiated which has the support of representative members, the A.S.M.E. through its members in those states, will offer to support the movement by helping to organize it further, by assisting to formulate a proper legislative bill, by soliciting the support of other engineering societies and outstanding members, by advising appropriate strategy, and by other suitable and proper means.

(4) In those states where registration laws have been enacted, the A.S.M.E., through its members, will encourage (*a*) amendment of the registration laws for the purpose of improving and making them more uniform, and (*b*) stricter enforcement of those laws.

The Committee on Registration was discharged with thanks and appreciation and the President was authorized to appoint a small committee to report in October on the procedure necessary to carry out the policy it had voted and to recommend the organization needed to enable the Society to assume leadership in registration activities.

ADVISORY BOARD ON STANDARDS AND CODES

A. D. Bailey, chairman, Advisory Board on Standards and Codes, reported that the Board did not favor the annual publication and distribution to each member of a complete volume of all technical committee reports, standards, and codes, but suggested that each year each member be furnished an annotated list of such material. Nor did the Board favor, he reported, the inclusion of the development of Power Test Codes and the A.S.M.E. Boiler Code under the procedure of the American Standards Association. The Council concurred informally in these views.

HANDBOOK ON METAL CUTTING

It was voted to accept the underwriting offered by the Engineering Foundation for the preparation of a manuscript of a handbook of metal-cutting data.

ESTIMATED INCOME AND COST OF ACTIVITIES FOR 1935–1936 ADOPTED BY THE COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, JUNE 18, 1935

Income	Actual for 1933–34	Revised budget for 1934–35	Budget for 1935–36
Initiation fees	$ 15,354.60	$ 12,000.00	$ 10,000.00
	$198,731.15	$200,000.00	$200,000.00
Student dues	6,781.35	9,700.00	10,500.00
Interest and discount	13,883.15	11,800.00	11,000.00
Mechanical Engineering, advertising	49,195.37	53,000.00	53,000.00
Mechanical Catalog	41,156.63	40,000.00	40,000.00
Publications sales	39,522.83	41,000.00	39,000.00
Miscellaneous sales	1,486.59	1,300.00	1,200.00
Journal of Applied Mechanics	.....	1,400.00	.....
Technical Committee Contributions	1,577.28	.....	.....
Contributions, unrestricted	982.06	.....	.....
	$353,316.41	$358,200.00	$354,700.00
Bad debts	3,972.33	1,000.00	1,000.00
	$349,344.08	$357,200.00	$353,700.00
Plus: Initiation fees	.....	12,000.00	10,000.00
		$369,200.00	$363,700.00
Bond retirement	.....	.....	4,600.00
			$359,100.00
Reduction of debt	.....	12,000.00	5,400.00
		$357,200.00	$353,700.00
Addition to surplus	.....	7,097.00	10,650.00
Budgetable income	.....	$350,103.00	$343,050.00

ESTIMATED COST OF ACTIVITIES FOR 1935–1936 ADOPTED BY THE COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, JUNE 18, 1935

Activities	Committee expense	Printing and distribution expense	Direct office expense	Direct cost
Council	$ 5,000.00	.....	.....	$ 5,000.00
Library	8,500.00	.....	.....	8,500.00
American Engineering Council	9,000.00	.....	.....	9,000.00
Sections	18,500.00	.....	$ 10,700.00	29,200.00
Meetings	5,700.00	.....	3,980.00	9,680.00
Divisions	2,400.00	.....	3,980.00	6,380.00
Branches	7,500.00	$ 2,600.00	6,630.00	16,730.00
Admissions	.....	.....	6,330.00	6,330.00
Employment	7,800.00	.....	2,090.00	9,890.00
Awards	450.00	.....	.....	450.00
Nominating Committee	750.00	.....	.....	750.00
Technical Committee	800.00	.....	16,080.00	16,880.00
Mechanical Engineering, Text	.....	21,900.00	10,060.00	31,960.00
Transactions	.....	25,000.00	9,730.00	34,730.00
Record and Index	.....	2,300.00	960.00	3,260.00
Mechanical Engineering, advertising	.....	10,000.00	19,140.00	29,140.00
Mechanical Catalog	.....	15,500.00	16,690.00	32,190.00
Publications for sale	.....	14,000.00	7,170.00	21,170.00
Secretary	.....	.....	14,950.00	14,950.00
	$66,400.00	$91,300.00	$128,490.00	$286,190.00
Interest and Discount	.....	.....	.....	5,000.00
General Office	.....	.....	.....	51,860.00
				$343,050.00

NOMINATING COMMITTEE

In view of the unavoidable absence from Cincinnati of both representative and alternate for Group I on the Nominating Committee, S. W. Dudley, was appointed representative of that group.

ARMY ORDNANCE ASSOCIATION

An invitation from the Army Ordnance Association to participate in its 17th Annual Meeting, Aberdeen Proving Ground, Maryland, October 3, 1935, was accepted.

S. F. VOORHEES

A resolution was voted extending to Stephen F. Voorhees, member, A.S.M.E., the appreciation and good wishes of the Council on his election to the presidency of the American Institute of Architects.

Proposed Amendments to A.S.M.E. Constitution

PROPOSED changes in the A.S.M.E. Constitution relating to membership grades are as follows:

ARTICLE C 3, MEMBERSHIP

Sec. 1 The voting membership shall consist of Fellows, Members, and Junior Members. In addition there shall be Honorary Members, Associates, and Student-members. *The corporate membership shall also include the members of the present Associate-Member grade until this grade is automatically eliminated.*[1]

Sec. 3 Each voting member shall be entitled to vote on any question before the Society.

ARTICLE C 4, QUALIFICATIONS FOR ADMISSION

Sec. 3 A Fellow shall be an engineer who shall have distinct engineering attainments, twenty-five (25) years of active practice in the profession of engineering or teaching of engineering in a school of accepted standing, and shall have been thirteen (13) years in the grade of Member, or *Associate-Member, or ten (10) years in the former Member grade.* Graduation from an engineering school of accepted standing shall be considered equivalent to four (4) years of active practice.

Sec. 4 An engineer lacking the qualifications of Section 3 who has distinguished engineering or scientific attainments may be elected a Fellow by unanimous vote of Council members voting.

Sec. 4 A All properly qualified past or present members of Council as of the date this Section is declared in effect shall become Fellows automatically upon application.

Sec. 5 A Member shall be an engineer or teacher of engineering who shall have reached the age of thirty (30) years and who shall have had nine (9) years in active practice in the profession of engineering or teaching, three (3) years of which shall have been in a position of responsible charge of important work, and who is qualified to design as well as direct such work. Graduation from a school of engineering of accepted standing shall be considered equivalent to four (4) years of active practice.

Sec. 5 A All present Associate-Members as of the date this Section is declared in effect and who shall have reached the age of thirty (30) years shall automatically be transferred to the grade of Member without fee or application, and those Associate-Members under thirty (30) years of age shall be transferred similarly as they reach the age of thirty (30) years.

Sec. 6 An Associate need not be an engineer but must have a record of recognized leadership in some profession, or branch of industry, or science relating to engineering, and shall be qualified to cooperate with engineers in the practice of their profession and he must be at least thirty (30) years of age.

Sec. 7 A Junior Member shall be a graduate of a school of engineering of accepted standing or one who has equivalent attainments.

Sec. 8 (*a*) A Student-member shall be a student regularly enrolled and pursuing an approved engineering curriculum in a school having a Student Branch of this Society.

(*b*) A Student-member may participate in all the activities of the Society but shall not be permitted to vote or hold an elective office except in the Student Branch located at the college of which he is a student.

(*c*) A Student-member shall not remain in this grade beyond the end of the Society's fiscal year in which he terminates his enrolment as a student.

ARTICLE C 5, FEES AND DUES

Sec. 1 Initiation fees for membership in each grade shall be:

Honorary Member	None
Fellow	$30
Member	$25
Associate	$25
Junior	$10
Student-member	None

Promotion fees shall be:

From Member to Fellow	$5
From Junior to Member	$10
From Junior to Associate	$10
From Student-member to Junior	None

Sec. 2 (Add provision for new grades)

Fellow	$25
Student-Member	As provided in the By-Laws

Sec. 3 The Council may permit any Fellow, Member, or Associate to become a Life Member in the same grade, as provided in the By-Laws.

[1] Subject matter in italics is to be eliminated by act of the Council without ballot of membership when the transition to the new scheme of membership grades is completed.

New Officers S.P.E.E.

AT THE recent annual meeting of the Society for the Promotion of Engineering Education, D. S. Anderson, dean of the College of Engineering, Tulane University, was elected president for the coming year. P. H. Daggett, dean, College of Engineering, Rutgers University, and S. B. Earle, dean of engineering and director of the Engineering Experiment Station, Clemson Agricultural College, South Carolina, member A.S.M.E., were elected vice-presidents. It was voted to hold the 1936 Annual Meeting at the University of Wisconsin, Madison, Wis.

A.E.C. News From Washington

THE clash between principle and method continue to make each day a lively one in Washington. The general situation with regard to the allotment of funds for engineering projects under the Works Relief Administration, as noted last month, has not changed. The general trend is toward small work-relief projects. Many of the large state projects are being broken down into small projects. Each state is a unit by itself in relation to the procurement of funds and some progress is being made by those states which are aggressively organized to secure funds.

The NRA seems practically defunct, at least in terms of its original purpose as a sort of super-management organization for industry. Those trade-practice relations that have grown up under codes that relate to prices and competitive trade practices are being gradually transferred to the Federal Trade Commission. Those parts of the codes having to do with labor are to be operated under the special bills, notably the Wagner Bill and the Guffey Bill. The only part of the NRA set-up which is functioning as originally intended, is the Research and Statistical Division, which of course has become a sort of centralized agency for the collection of general business information.

What might be termed the mass-educational program for business men which has been conducted by trade associations and by code authorities on the improvement of business practice, is being continued under so-called voluntary agreements in which many of the trade associations have taken the initiative. In New York, for example, a council on trade agreements has been developed by the Trade Association Executives' Organization of New York in cooperation with the American Arbitration Association.

THE FEDERAL HOUSING ADMINISTRATION

Under the plan of insuring loans for industrial rehabilitation, the possibilities of plant modernization are being pushed by the Federal Housing Administration. Our understanding is that there are many applications involving engineering improvements in machinery and equipment. The Federal Housing Administration does not supply the money for these, but insures loans from other sources. This development is of considerable engineering significance in so far as it improves the possibilities of credit for loans for capital goods.

PERSONNEL: ENGINEERING EMPLOYMENT

Comparatively few positions are expected to develop in Washington, but much activity is expected in the states under the direction of state administrators of the Works Progress Administration. State organizations are being formed now and engineers seeking employment should be advised to communicate with the state administrators of the Works Progress Administration.

Instructions to the state administrators tell them not to engage in or make use of politics in connection with the execution of the Works Relief Program, but appointments and assignments indicate that political sponsorship in the state may be as necessary as similar approval in Washington.

Engineers serving in administrative, consulting, professional, and supervisory capacities will be paid salaries and fees slightly less than those prevailing in the area where they are employed. Engineers on relief rolls must work for a maximum of $94 per month until they reach the place where they can "strike out for themselves."

BUREAU OF LABOR STUDY

The Cooperative Survey of the Engineering Profession was an assured success when the final deadline for receipt of questionnaires fell on July 8. As this is written, it is impossible

(*Continued on page 534*)

COUNT *the Production Steps* saved by Bakelite Molded!

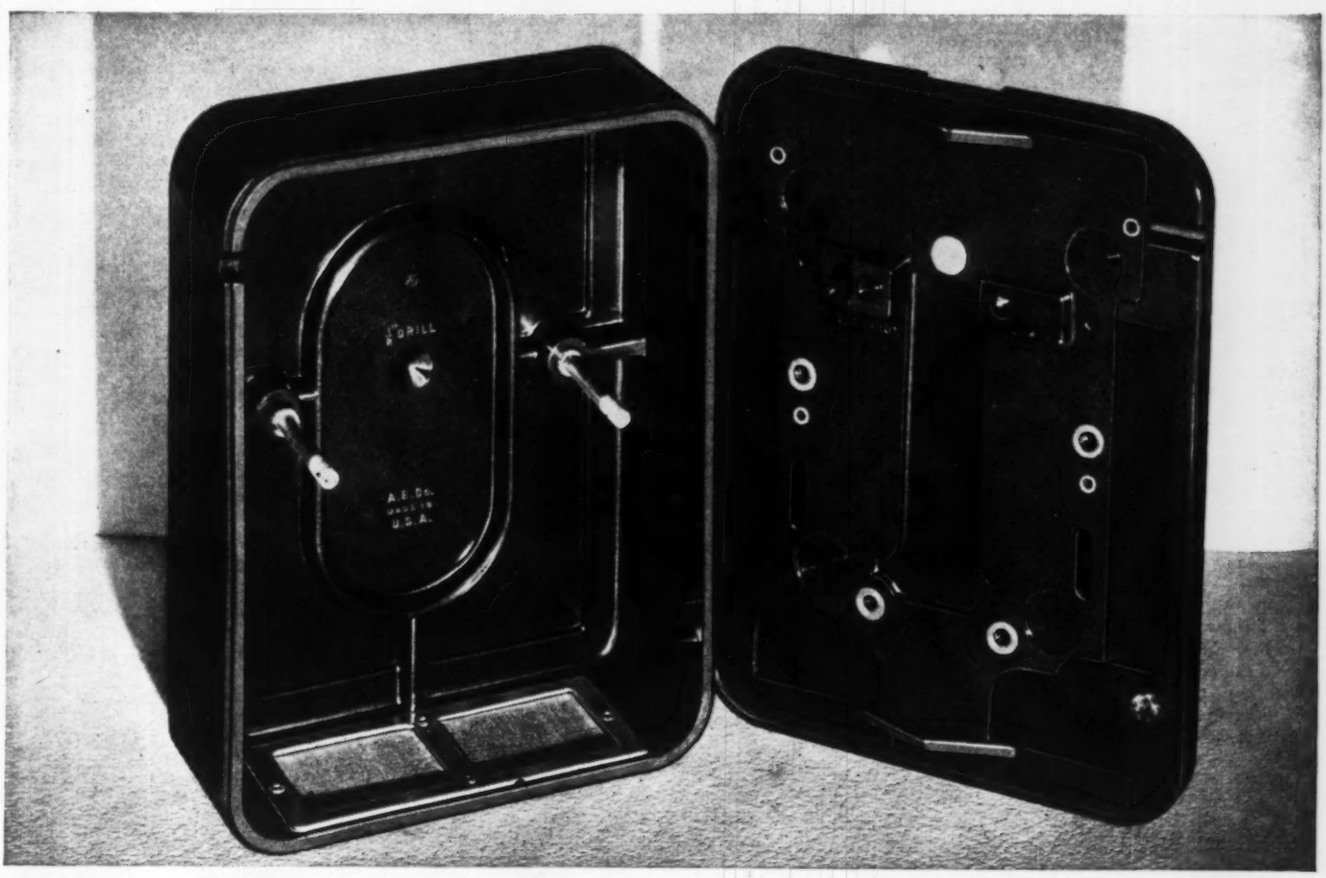
HERE IS a clear-cut example of the manufacturing economies made possible by Bakelite Molded. It is the Strowger telephone ringer box and cover, made by Automatic Electric Co., Chicago. Each one of these two parts is completely formed in one simple press operation.

Threaded bronze inserts for holding electrical parts in place are accurately positioned and embedded during the molding operation. All necessary recesses, bosses, grooves and through holes are formed at the same time. Box and cover leave the mold precision-made, and with a permanently lustrous finish that requires neither enameling nor polishing.

The use of Bakelite Molded thin section, deep cavity shapes often saves trimming, drilling, punching, tapping, welding and finishing. In addition, it brings greater compactness in design, simplification in assembly and definite improvement in appearance.

Many manufacturers of products or parts formerly pressed or machined from metal or other materials are effecting decided improvements and economies with Bakelite Molded. The toughness and strength of this material, combined with its chemical and thermal resistance and electrical insulation value, offer unusual advantages for an endless variety of uses.

We would be glad to consult with you on your particular problems. Write for our illustrated Booklet 32M "Bakelite Molded", which describes and illustrates diversified applications in numerous manufacturing fields.



BAKELITE CORPORATION, 247 Park Avenue, New York, N.Y. . . . . 43 East Ohio Street, Chicago, Ill.
BAKELITE CORPORATION OF CANADA, LIMITED, 163 Dufferin Street, Toronto, Ontario, Canada

BAKELITE

REGISTERED U.S. PAT. OFF.

The registered trade marks shown above distinguish materials manufactured by Bakelite Corporation. Under the capital "B" is the numerical sign for infinity, or unlimited quantity. It symbolizes the infinite number of present and future uses of Bakelite Corporation's products.

THE MATERIAL OF A THOUSAND USES

to arrive at the exact number of blanks received. Some will have to be weeded out because they come from men not properly qualified as engineers. But the number is ample to provide a good cross-section of the engineering fraternity and to chart its situation through the depression years. As soon as the pressure of urgent federal work permits, the Bureau of Labor Statistics will tabulate the results so that complete data will be available for planning the future course of the profession.

National Applied Mechanics Meeting, June 18–19

UNDER the auspices of the Detroit Section of The American Society of Mechanical Engineers, the Applied Mechanics Division of the Society, and the University of Michigan, the Third National Applied Mechanics Meeting was held at Ann Arbor, Mich., June 18 and 19.

The program of the meeting, which appeared on page 395 of the June issue of MECHANICAL ENGINEERING, included seven papers on elasticity, three on the strength of materials, and three on vibrations and dynamics. The one hundred and twenty persons who attended the meeting were fortunate in being able to listen to the presentation of each paper by its author, and to animated discussion of the subject matter.

Inspections of the materials-testing, engineering, and physics laboratories of the University were features of the program. At the joint dinner on Tuesday night J. Ormondroyd spoke on "Some Thoughts on the Teaching of Dynamics to Engineering Students."

A report from the meeting mentions specifically the lively discussion on thermal stresses in plates and cylindrical shells, which was the subject of the paper by J. P. Den Hartog. The paper gave methods of calculating stresses produced by non-uniform heating of plates in various cases of welding.

The paper by Peterson and Wahl presented the results of direct stress measurement at the fillets of a shaft of large diameter and showed that these stresses approximate very closely those obtained by photoelastic methods. Mr. Horger, at the same session, showed interesting experimental results dealing with improving the fatigue characteristics of shafts by cold-working their surfaces.

At the session on vibration it was shown how, by proper design, the nosing of a locomotive at high speed can be eliminated.

W. E. Wickenden Awarded Lamme Medal

WILLIAM ELGIN WICKENDEN, president, Case School of Applied Science, Cleveland, Ohio, and member, A.S.M.E., was awarded the eighth Lamme medal of the Society for the Promotion of Engineering Education at its forty-third annual meeting, Atlanta, Ga., June 26, 1935.

President Wickenden has had a distinguished career as personnel director and educator, and as director of the S.P.E.E. investigation of engineering education in 1924.

Engineers' Council Offers to Accredit Engineering Schools

THE Engineers' Council for Professional Development sponsored by the leading national engineering societies, the engineering educators, and the engineering examiners, has announced the inauguration of a program for accrediting engineering schools in New England and the Middle Atlantic States. The program will be offered to the other parts of the country after a trial period in these two regions. Notice is being sent to the presidents of all degree-granting engineering schools in the two areas advising them that the Engineers' Council stands ready to receive requests for consideration of particular engineering curricula which the schools may wish to submit.

Through the E.C.P.D. Committee on Engineering Schools, regional subcommittees have been organized to visit each institution requesting recognition for its curricula. The visits by these committees will begin early in the fall, and it is expected that the accrediting in these regions will be well under way before the first of the year. The plans and procedures will be considered in the light of the experience in carrying out the accrediting process in these regions, and with such modifications as seem desirable, the plan will then be offered to the other parts of the country.

Accrediting is necessary at the present time for a number of reasons, the most urgent of which is the fact that a majority of the states have enacted laws for the licensing of engineers, and that licensing procedure requires a list of accredited colleges whose graduates may submit evidence of their graduation in partial fulfilment of the requirements of licensure. The Engineers' Council for Professional Development is undertaking this work because it is the only body which represents all of the interested groups: The engineering schools, the state licensing boards, and the national engineering societies.

While the primary purpose of E.C.P.D. through its Committee on Engineering Schools is to identify those institutions which offer professional curricula in engineering worthy of recognition as such, in longer range the purpose is to aid in promoting the best interests of engineering education and to raise the general level of its effectiveness. Emphasis will be given to quality of work, rather than to statistical information, to a greater degree than in former accrediting procedures. No hard and fast prescriptions are laid down for curricula, physical facilities, investments or expenditures, or other specific points relating to a given institution, although all of these, and others, will be taken into account in appraising the institution as a whole.

Great progress has been made in certain of the professions in raising the standards of their professional schools. The most notable of these is the medical profession. It is believed that this program of E.C.P.D. is an important part of the broader plan for enhancing the status of the engineering profession.

The constituent organizations of the Engineers' Council for Professional Development are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society for the Promotion of Engineering Education, American Institute of Chemical Engineers, and National Council of State Boards of Engineering Examiners.

Program of A.S.M.E. Machine Shop Sessions at Machine Tool Congress at Cleveland

MORE detailed information is now available of the program to be sponsored by the A.S.M.E. Machine Shop Practice Division and the Cleveland Local Section at evening sessions, September 11 and 12, during the Third National Machine Tool Congress to be held in Cleveland from September 11 to 21. Both of these sessions will be held at the Hotel Statler.

The Wednesday evening session on September 11 will open with an address of welcome by C. R. Burt, president of the Pratt & Whitney Co., Member, A.S.M.E., and will be followed by two papers. The first of these will be on "Surface Finishing by Cylindrical Grinding," by Howard W. Dunbar, manager of the Grinding Division of the Norton Company. The second paper is entitled "Internal Surface Finishing," by A. W. Schneider, of the Heald Machine Company. The session will have as its presiding officer Philip E. Bliss, president of the Warner & Swasey Co., Cleveland.

On Thursday evening, September 12, there will be an informal dinner at 6:30 p.m., at which Kenneth Condit, editor of the *American Machinist* and member, A.S.M.E., will give a talk on "Machine Shops in Nazi Germany." Presiding at the dinner will be McRea Parker, Director of Schools, Cleveland, Ohio.

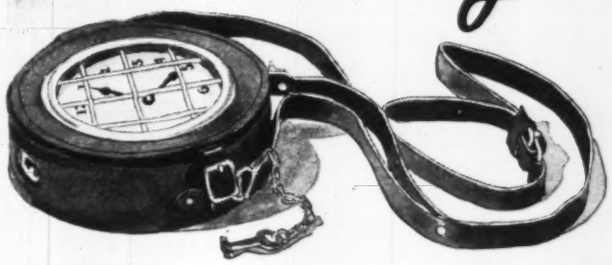
The evening session will start at 8 p.m., with James H. Herron, vice-president, A.S.M.E., consulting engineer, Cleveland, as presiding officer. Two papers will be presented, "Cemented Carbide Cutting Material," by Roger D. Prosser, associate-member, A.S.M.E., of Thomas Prosser & Son; and "Modern Metal Cutting-Motion Pictures Taken Through the Microscope, Showing the Action of a Cutting Tool in Removing a Chip," by Hans Ernst, member, A.S.M.E., of the Cincinnati Milling Machine Co.

Application blanks for reduced-fare certificates will be sent to the entire United States and Canadian membership of the A.S.M.E. but it will be necessary for the individual member who wishes one of these certificates to apply for it, and *no certificate can be obtained unless an application is received.*

Hotel accommodations may also be obtained by applying directly to the headquarters of the National Machine Tool Builders Association, 1220 Guarantee Title Building, in Cleveland. A housing committee has been appointed to take care of these requests and members will be assigned to whichever hotel they may prefer, assuming, of course, that reservations can still be made.

(Continued on page 536)

Every Hour on the Hour



■ Typical! Adjacent to Chicago's loop with its scores of skyscrapers—Crane's service knows no 8-hour day. At night, every hour on the hour, a watchman arrives at the entrance to admit loop maintenance men seeking parts, valves, and fittings for their respective buildings.

Maintenance men can tell you better than we can the advantages of a completely Crane-equipped plant, with instant interchangeability of many parts, constant, ever-ready supply, absolute uniformity, and the money-saving, worry-saving feature of one responsibility for every part of the plant piping.

With Crane valves, fittings and fabricated piping you have uniform reliability. And this grows more important each day as production increases, and there is a vital need to "keep going" in response to demand.

CRANE SHOP FABRICATION SERVICE

Design	Flanging
Casting	Cutting
Bending	Threading
Welding	Assembling

There is a Crane Valve or fitting for every piping requirement

NON-CORROSIVE

Crane 18-8 Alloy Screwed and Flanged Valves

1 Crane 18-8 Chrome Nickel Alloy valves are made from standard patterns to insure interchangeability of renewable parts.

2 "18-8," as produced by Crane, offers excellent resistance to corrosive action of many chemicals.

3 A complete line of Crane 18-8 pipe fittings also is available.

4 Crane Metallurgical Laboratories accurately control the production of Crane special alloy valves and fittings.

5 Crane has a vast fund of laboratory and practical experience on which to base recommendations on corrosion resisting piping materials.

CRANE VALVES, FITTINGS and PIPE FABRICATION

CRANE CO., GENERAL OFFICES: 836 SO. MICHIGAN AVE., CHICAGO, ILL. • NEW YORK: 23 W. 44TH STREET

Branches and Sales Offices in One Hundred and Sixty Cities